

NATURAL HISTORY,

GENERAL AND PARTICULAR,

BY THE

COUNT DE BUFFON,

TRANSLATED INTO ENGLISH.

ILLUSTRATED

WITH ABOVE 300 COPPER-PLATES,

AND OCCASIONAL

NOTES AND OBSERVATIONS.

BY WILLIAM SMELLIE,

MEMBER OF THE ANTIQUARIAN AND ROYAL
SOCIETIES OF EDINBURGH.

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C O N T E N T S.

Page:

ADDITIONS to the Article concerning the Formation of the Planets.

- | | |
|--|---|
| I. <i>On the Distance of the Earth from the Sun</i> | 1 |
| II. <i>Of the Matter of the Sun and Planets</i> | 3 |
| III. <i>Of the Relation between the Density of the Planets and their Celerity</i> | 4 |
| IV. <i>On the Relation assigned by Newton between the Density of the Planets and the degrees of Heat to which they are exposed</i> | 6 |

ADDITIONS to the Article concerning Geography.

- | | |
|--|----|
| I. <i>On the Extent of Terrestrial Continents</i> | 8 |
| II. <i>Of the Form of Continents</i> | 12 |
| III. <i>Of the Terra Australis</i> | 14 |
| IV. <i>Concerning the Invention of the Mariner's Compass</i> | 16 |
| V. <i>Of the Discovery of America</i> | 17 |

A D-

iv C O N T E N T S.

Page.

A D D I T I O N S to the Article, Of the Production of Strata.

- | | |
|---|----|
| I. <i>Concerning the Strata in different Parts
of the Earth</i> | 22 |
| II. <i>Of the Interior Rock of the Globe</i> | 30 |
| III. <i>Of the Vitrification of Calcareous Sub-
stances</i> | 32 |

A D D I T I O N S to the Article concern- ing Shells, and other Productions of the Sea, found in the Interior Parts of the Earth.

- | | |
|--|----|
| I. <i>Of Fossil and Petrified Shells</i> | 34 |
| II. <i>Of the Places where Shells are found</i> | 38 |
| III. <i>Of those great Volutes called Cornua
Ammonis, and of some large Bones of
Terrestrial Animals</i> | 47 |

A D D I T I O N S to the Article, Of the Inequalities of the Surface of the Earth.

- | | |
|---|----|
| I. <i>Of the Height of Mountains</i> | 50 |
| II. <i>Of the Direction of Mountains</i> | 55 |
| III. <i>Of the Formation of Mountains</i> | 60 |
| IV. | |

C O N T E N T S.

Page.

IV. *Of the Density which certain Matters acquire by Fire, as well as by Water* 63

V. *Of the Inclination of the Strata in the Mountains* 67

VI. *Of the Peaks of Mountains* 70

ADDITIONS to the Article, Of Rivers.

I. *Additional Observations on the Theory of Running Waters* 72

II. *Of the Saltiness of the Sea* 75

III. *Of perpendicular Cataracts* 76

ADDITIONS and Corrections to the Article, Of Seas and Lakes.

I. *Of the Limits of the South Sea* 78

II. *Of double Currents in some Parts of the Ocean* 79

III. *Of the Northern Parts of the Atlantic Ocean* 86

IV. *Of the Caspian Sea* 99

V. *Of the Salt Lakes of Asia* 102

ADDITIONS and Corrections to the Article, Of Inequalities at the Bottom of the Sea, and of Currents.

I.

CONTENTS.

	Page.
I. <i>Of the Nature and Quality of the Soil at the Bottom of the Sea</i>	104
II. <i>Of Currents in the Ocean</i>	107

ADDITIONS to the Article, Of Regular Winds.

I. <i>Of Reflected Wind</i>	116
II. <i>Of the State of the Air at the Top of high Mountains</i>	117
III. <i>Of some Winds which have a regular Variation</i>	123
IV. <i>Of Lavanges, or great Masses of Snow and Ice rolling down from high Mountains</i>	125

ADDITIONS to the Article, Of Irregular Winds, Water-Spouts, &c.

I. <i>Of the Violence of the South Winds in some Northern Countries</i>	128
II. <i>Of Water-Spouts</i>	129

ADDITIONS to the Article, Of Earthquakes and Volcano's.

I. <i>Of Earthquakes</i>	138
II.	

C O N T E N T S. vii

	Page.
II. Of Volcano's	146
III. Of the Changes which have happened in Volcano's	147
IV. Of Extinguished Volcano's	193
V. Of Lavas and Basalts	209

A D D I T I O N S to the Article, Of Caverns.

Of Caverns formed by the Primitive Fire 222

A D D I T I O N S to the Article, Of the Effect of Rains, Marshes, Subterraneous Wood and Water.

I. Of the Sinking and Derangement of certain Lands	228
II. Of Turf	233
III. Of Subterraneous, Petrified, and Char- red Wood	237
IV. Of Bones sometimes found in the In- terior Parts of the Earth	249

A D D I T I O N S to the Article, Of the Changes of Sea into Land. 255

<i>Facts and Arguments concerning the Epochs of Nature</i>	<i>258</i>
<i>Of the Elevation of the Earth at the Equa- tor, and its Depressiion at the Poles</i>	<i>261</i>
<i>Of</i>	

	Page.
<i>Of the Internal Heat of the Globe</i>	262
<i>Of the Materials of which the Globe is composed</i>	269
<i>Of the Monuments of Nature</i>	274
<i>Reasons why the Bones of Elephants and other Animals which now inhabit only the Southern Climates, are found in Siberia and North America</i>	275
<i>Of enormous Teeth and other Bones found in Canada near the river Ohio</i>	288
<i>Of Metallic Veins and Metals</i>	307
<i>Of Mountains composed of Load-stone</i>	314
<i>Of Shells found in different Places and Situations</i>	318
<i>Of Fishes living in warm Fountains</i>	321
<i>Of Giants</i>	325
<i>Of Fishes and Plants found in Coal and Slate</i>	341
<i>Of the Nature of Coal, and of Fossil Wood</i>	343
<i>Of the Declivity of Coasts</i>	349
<i>Description of the Maillés, a Savage Nation</i>	351
<i>Remarks on the Caspian Sea</i>	352
<i>Of the Submersion of Taprobana</i>	353
<i>Remarks on Guiana</i>	355
<i>Of the Glaciers</i>	358
<i>Of the North-East Passage</i>	367
<i>Concerning that Period when the Powers of Man aided those of Nature</i>	381



transit of Venus over the sun's disc in 1769, show that the distance of thirty millions should be augmented three or four millions of leagues.

NATURAL HISTORY.

Now, I have always reckoned the mean distance of the sun from the earth to be thirty-three millions of leagues, instead of thirty. This remark was necessary to prevent the inference of my having contracted my style.

I must farther remark, that the sun is not only thirty-three or thirty-four millions of leagues

ADDITIONS AND CORRECTIONS.

Observations, it has likewise been discovered that the volume of the sun is a tenth part larger than was formerly supposed; and consequently

ADDITIONS to the Article concerning the Formation of the Planets, Vol. I. p. 59.

varied from the information we possessed in the year 1745. The distance of the planets was probably that the matter I. ejected from the body of the sun.

On the distance of the Earth from the Sun.

IN p. 59. I said, *That the earth is situated thirty millions of leagues from the sun.* This was the general opinion of astronomers in the year 1745, when I composed the treatise on the formation of the planets. But later observations, and particularly those derived from the

transit of Venus over the sun's disc in 1769, show that this distance of thirty millions should be augmented three or four millions of leagues. It is for this reason that, in the *Epoques de la Nature*, I have always reckoned the mean distance of the sun from the earth to be thirty-three millions of leagues, instead of thirty. This remark was necessary to prevent the suspicion of my having contradicted myself.

I must farther remark, that the sun is not only thirty-three or thirty-four millions of leagues distant from the earth, but, from the same observations, it has likewise been discovered that the volume of the sun is a tenth part larger than was formerly supposed; and, consequently, that the whole mass of the planets is only an eight hundredth part of that of the sun, and not a six hundredth and fiftieth part, as I had advanced from the information we possessed in the year 1745. This difference strengthens the probability that the matter of the planets was projected from the body of the sun.



OF THE PLANETS.

3

II.

Of the Matter of the Sun and Planets.

I HAD remarked, in p. 65: That *the opaque bodies of the planets were detached from the luminous matter of which the sun is composed.* These expressions are not correct; for the matter of the planets, when projected from the sun, was equally luminous as that of the sun itself, and the planets became not opaque till their state of fluid brightness had ceased: The duration of this state in several kinds of matter I determined by experiment; and, from analogy, I calculated the continuation of this bright state in each of the planets *. Besides, as the torrent of matter, projected from the body of the sun by the comet, traversed the immense atmosphere of that luminary, it carried off the volatile, aqueous, and aerial parts of which the seas and atmospheres of the different planets are now composed. Hence we may conclude, that the matter of the planets is the same, in every respect, with that of the sun, and that there is no other difference but in the degree of heat, which is extreme in the sun, and greater or smaller in the planets, according to the compound ratio of their thickness and density.

A 2

III.

* See epoques de la nature.

III.

Of the relation between the Density of the Planets and their Celerity.

IN p. 75. I said, that, *according to this relation between the celerity and density of the planets, the density of the earth ought not to exceed $206\frac{7}{18}$, instead of 400, which is its real density.* The density here ascribed to the earth is too great with relation to the quickness of its motion round the sun, and ought to be a little diminished for a reason which had formerly escaped me. The moon, which, in this computation, should be regarded as forming a part of the earth, is less dense in the ratio of 702 to 1000, and the lunar globe is $\frac{1}{49}$ th of the bulk of the terrestrial. Hence, if the moon were as large as the earth, we should diminish the density of the latter 400 in the ratio of 1000 to 702, which produces 281, *i. e.* 119 of diminution in the density 400. But, as the moon is only $\frac{1}{49}$ th part of the bulk of the earth, it will produce only $\frac{119}{49}$, or $2\frac{2}{7}$ ths of diminution. Consequently, the density of our globe, with relation to its celerity, instead of $206\frac{7}{18}$, ought to be estimated at $206\frac{7}{18} + 2\frac{2}{7}$ *i. e.* nearly 209. Besides, we may suppose that our globe, at the beginning, was less dense than it is at present, and that it is become much more compact both
by

by cooling, and by the sinking of vast caverns with which its interior parts abounded. This opinion accords with those revolutions which happened, and still continue to happen, both on the surface of the earth, and even at considerable depths. By the aid of this fact, we are enabled to explain the possibility that the waters of the sea were formerly 2000 fathoms above those parts of the globe which are now inhabited; for these waters would still cover the whole surface of the earth, if, by immense depressions, different parts had not sunk, and formed those receptacles for the waters which at present exist.

If we suppose the diameter of the globe to be 2863 leagues, it would be two leagues more when covered with 2000 fathoms of water. This difference in the bulk of the earth, produced by the sinking of the waters, gives an augmentation of a $\frac{1}{477}$ th part of its density. This augmentation of the density, or diminution of the bulk of the globe, may be doubled, and perhaps tripled, by the sinking and overturning of mountains, and the consequent filling up of valleys; so that, since the waters fell upon the earth, its density may be supposed to have increased one hundredth part.

IV.

On the relation assigned by Newton between the density of the Planets and the degrees of Heat to which they are exposed.

IN p. 145. I remarked, that, notwithstanding the regard due to the conjectures of Newton, I cannot help thinking that the densities of the planets have a nearer relation to their celerities than to the degrees of heat to which they are exposed. From calculating the action of the solar heat upon the planets, it appears that this heat, in general, is inconsiderable, and that it has never produced any great change in the density of each planet; for the action of the solar heat, which is weak in itself, has no influence on the density of the matter of which the planets are composed, except at their surfaces. It cannot act on the internal parts, because it penetrates to a very small depth only. Hence the total density of a planet has no relation to the heat transmitted to it by the sun.

It appears to be certain, therefore, that the density of the planets has no dependence on the solar heat, but, on the contrary, that their densities have a necessary relation with their celerities, which last increase or diminish in proportion to their

their distances from the sun. We have seen, that, at the general projection, the more dense parts were not removed so far from the sun as the less dense. Mercury, which is composed of the most dense matter projected from the sun, remained in the neighbourhood of that luminary; while Saturn, which consists of the lightest matter, is removed to a great distance from the sun: And, as the most distant planets revolve round the sun with greater celerity than those that are nearer, it follows, that their density has a direct relation with their celerity, and still more with their distance from the sun. The distances of the six planets from the sun are as 4, 7, 10, 15, 52, 95; and their densities as 2040, 1270, 1000, 730, 292, 184. And, if we suppose the densities to be in the inverse ratio of the distances, they will be as 2040, 1160, 889 $\frac{1}{2}$, 660, 210, 159. This last relation between their respective densities is perhaps more just than the former; because it seems to be founded on the physical cause which must have produced the difference of density in each planet.

ADDITIONS

8 OF GEOGRAPHY.

ADDITIONS to the Article concerning Geography, Vol. I. n. 133.

I.

On the extent of Terrestrial Continents.

PAGE 134. I said, that *the longest line which can be drawn in the ancient Continent is about 3600 leagues.* By leagues I mean those used in the environs of Paris, which are 2000 or 2100 fathoms long, and about 27 of them make a degree.

Besides, though in this article of general geography, I endeavoured to reach that degree of exactness which subjects of that nature require; yet a few slight errors have escaped me. For example, 1. I have not used the names adopted or given by the French to several parts of America. I uniformly followed the British globes made by Senex, of two feet diameter, from which my charts were exactly copied. The British are more just than the French, with regard to countries they discover, or through which they travel. They preserve the original name of each country, or that which was bestowed on it by the first discoverers. We, on the contrary, often give French names to the countries we visit, which is the cause of that obscurity in the geographical nomenclature of our language. But, as the lines which traverse the two Continents

OF GEOGRAPHY. 9

nents in their greatest length are well marked, in my charts, by the two extreme points, and several other intermediate ones, whose names are generally adopted, no essential ambiguity can arise from this circumstance.

2. I likewise neglected to give the calculation of the surface of the two continents, because it is easily made on a large globe. But, as many persons have expressed a desire to see this calculation, I here subjoin that which M. Robert de Vaugondi transmitted to me at the time*.

From

* Calculation of our Continent by geometrical leagues square.

14 d.	14 d.	14 d.	14 d.	14 d.
5 E	8 D	10 $\frac{1}{2}$ C	12 $\frac{1}{2}$ B	13 $\frac{1}{2}$ A
78750	80937	100625	113750	120312 $\frac{1}{2}$

Calculation of the left half.

Calculation of the right half.

A × 3 =	360937 $\frac{1}{2}$
A × 3 $\frac{1}{2}$ =	421093 $\frac{3}{4}$
B × 3 $\frac{1}{2}$ =	398125
B × 4 =	455000
C × 2 =	201250
C × 3 =	301875
D × 1 =	80937 $\frac{1}{2}$
D × 2 =	161874
E × 1 =	78750
E × $\frac{1}{4}$ =	11250
<hr/>	
	2471092 $\frac{1}{2}$

A × 3 =	360937 $\frac{1}{2}$
A × 1 =	120312 $\frac{1}{2}$
B × 1 =	113750
B × 4 $\frac{1}{2}$ =	492916 $\frac{1}{2}$
C × 1 =	100625
C × 4 $\frac{1}{2}$ =	436041 $\frac{1}{2}$
D × 1 =	80937 $\frac{1}{2}$
D × 4 $\frac{1}{2}$ =	350729
E × 1 =	78750
E × 4 $\frac{1}{2}$ =	334687 $\frac{1}{2}$
<hr/>	
	2469687

2471092 $\frac{1}{2}$
2469687

Difference 1405 $\frac{1}{2}$

Which is scarcely a degree and a half square.

10 OF GEOGRAPHY.

From this calculation it appears, that, on the left of the line of partition, there are $2471092\frac{3}{4}$ of square leagues, and 2469687 square leagues on the right of the same line ; and consequently that the Old Continent consists of about 4940780 square leagues, which is not one fifth part of the earth's surface.

In the same manner, the part on the left of the line of partition in the New Continent, contains $1069286\frac{5}{8}$ square leagues, and that on the right of the same line consists of $1370926\frac{1}{12}$;
in

Calculation of the Continent of America according to the same measures.

Calculation of the left half.		Calculation of the right half.	
D \times 2 =	161965	D \times $2\frac{3}{4}$ =	215833 $\frac{1}{4}$
C \times 2 =	201250	C \times $2\frac{1}{4}$ =	225406 $\frac{1}{4}$
B \times 2 =	227500	A \times $1\frac{1}{2}$ =	24062 $\frac{1}{2}$
A \times $1\frac{1}{3}$ =	60156 $\frac{1}{3}$	A \times $1\frac{1}{2}$ =	144375
A \times $1\frac{2}{3}$ =	80208 $\frac{1}{3}$	B \times 2 =	227500
B \times $1\frac{4}{5}$ =	91000	C \times $2\frac{1}{2}$ =	218020
C \times $1\frac{1}{4}$ =	125801 $\frac{1}{4}$	D \times $1\frac{1}{2}$ =	15750
D \times 2 =	121406		
	<hr/>		<hr/>
	1069286 $\frac{5}{8}$		1070926 $\frac{1}{12}$
	<hr/>		<hr/>
			1070926 $\frac{1}{12}$
			1069286 $\frac{5}{8}$
			<hr/>
			Difference
			1639 $\frac{1}{4}$

Which is scarcely a degree and one fifth square.

Superficies of the New Continent	2140213
Superficies of the Old Continent	4940780
	<hr/>
Total	7080993 square leagues.

in all, about 2140213 square leagues; which makes not one half of the surface of the Old Continent. As both Continents contain but 7080993 square leagues, their superficies is not near one third of the total surface of the globe, which is about 26 millions of square leagues.

3. I ought to have mentioned the small difference of inclination that subsists between the two lines by which I divided the two Continents. I contented myself with saying, that they were both inclined to the Equator, in opposite sides, about 30 degrees, which is not the precise fact; for that of the Old Continent is a little more than 30 degrees, and that of the New a little less. If I had given this explanation, I should have avoided the imputation of having drawn two lines of unequal lengths, under the same angle between two parallels; which would have proved, as an anonymous critic remarks *, that I am unacquainted with the elements of geometry.

4. I neglected to distinguish Upper from Lower Egypt; so that, in p. 137. and 138. there is the appearance of a contradiction. In the first of these passages, Egypt seems to be ranked among the most ancient lands, while, in the second, it is reckoned among the most recent. I was wrong in not distinguishing, as I had elsewhere done, Upper Egypt, which is a very ancient land, from Lower Egypt, which is a very new territory.

II.

* Lettres à un Americain.

II.

Of the Form of Continents.

With regard to the figure of Continents, I shall transcribe a passage from the ingenious author of the Philosophical and Political History of the two Indies.

‘ It is now thought to be certain,’ he remarks, ‘ that the surface of the New Continent is not one half of that of the Old. Besides, in their figure there are some striking analogies.—They seem to form two immense bands of earth, which arise from the Arctic pole, terminate in the South, and separated on the East and West by the ocean that invests them. Independent of the structure of these two bands, and of the counterpoise or symmetry which takes place in their figure ; it is apparent, that their equilibrium depends not on their position ; it is the fluctuation of the sea which produces the stability of the earth. To fix the globe on its base, it was necessary to have an element which, by floating continually around this planet, should counterbalance, by its weight, the other substances, and restore that equilibrium which the collision of the other elements might have disturbed. Water, by its fluidity and gravity, is well fitted

‘fitted to support that harmony and that balance
 ‘of the different parts of the globe around its
 ‘centre.

‘If the waters which still moisten the bowels
 ‘of the New Hemisphere had not deluged its
 ‘surface, man would soon have cut down the
 ‘woods, drained the marshes, and given consist-
 ‘ence to a watery soil.—He would have opened
 ‘vents to the winds, and confined the rivers
 ‘within their banks; the climate, of course,
 ‘would have already been changed. But an
 ‘uncultivated and thinly inhabited hemisphere
 ‘announces a recent land, while the waters
 ‘which environ its coasts still creep silently
 ‘through its veins.’

On this subject I shall remark, that, although there is more water on the surface of America than on that of other countries, we ought not to conclude from this circumstance, that an internal sea is contained in the bowels of this new land. We should only infer from this number of lakes, marshes, and large rivers, that America has been peopled long after Asia, Africa, and Europe, where the quantity of stagnant waters is much less. Besides, a thousand other circumstances concur in showing, that the Continent of America in general ought to be regarded as new land, in which Nature has not had time to acquire all her powers, nor to exhibit them by a numerous population.

III.

Of the Terra Australis, p. 140.

To what I have said concerning the Terra Australis, I shall add, that, within these few years, new attempts have been made to discover it, and that some points of it have been found after departing either from the Cape of Good Hope, or from the Isle of France; but that these new voyagers have uniformly met with thick fogs, snow, and ice, in the 46th or 47th degree of South latitude. After conversing with some of these voyagers, and collecting all the information I could derive from other sources, I perceived that they all agreed with regard to this fact, and that they found ice in much lower latitudes than is to be met with in the northern hemisphere. They likewise uniformly met with fogs in the same latitudes where they found ice, though it was summer in these climates at the time the experiments were made. It is, therefore, extremely probable, that, below the 50th degree, it will be in vain to search for temperate countries in the southern hemisphere, where the freezing cold is much farther extended than in the northern. The thick fog is produced by the presence or neighbourhood of the ice. This
fog

fog consists of minute particles of snow, which are suspended in the air, and render it obscure : It often accompanies the great floating masses of ice, and reigns perpetually in frozen regions.

Besides, the British have lately sailed round New Holland as well as New Zealand. These southern countries are more extensive than the whole of Europe. New Zealand is divided into several islands ; but New Holland ought rather to be regarded as a part of Asia, than as an island belonging to the Southern Continent ; for New Holland is only separated from the land of the Papous, or New Guiney, by a narrow strait, and the whole Archipelago, which extend southward from the Philippine isles, as far as the country of Arnheim in New Holland, and toward the west and south, as far as Sumatra and Java, appears to belong as much to the Continent of New Holland, as to the southern parts of Asia.

Captain Cook, who ought to be regarded as the greatest navigator of this age, and to whom we are indebted for an infinite number of new discoveries, has not only given a chart of the coasts of Zealand and New Holland, but has likewise explored an immense tract of the south sea in the neighbourhood of America. He departed from the south point of America on the 30th of January 1769, and he traversed a great part of the ocean under the 60th degree, without discovering any land. From Captain Cook's chart
we

we may perceive the great extent of sea which he explored ; and his tract demonstrates, that, if any lands exist in this part of the globe, they must be far removed from the Continent of America ; for New Zealand, which is situated between the 35th and 45th degrees, is very distant from America. But it is still to be hoped, that other navigators, following the tract of Captain Cook, will traverse the southern ocean under the 50th degree, and that they will discover whether these immense regions, which extend more than two thousand leagues, consist of land or of sea. However, I do not imagine that the southern regions, beyond the 50th degree, are so temperate that any advantage could be derived to us from the discovery of them.

IV.

Concerning the invention of the Mariner's Compass, p. 153.

With regard to the invention of the Mariner's Compass, I have to add, that, from the testimony of Chinese authors, of which M. le Rouse and M. de Guignes have made an abridgement, it appears to be certain, that the polarity of the magnetic needle has been very anciently known to the inhabitants of China. The figure of these
first

first compasses was those of a man, who turned upon a pivot, and whose right arm pointed to the south. The time of this invention, according to certain Chinese chronicles, was 1115 years before the Christian aera, and, according to others, 2700 *. But, notwithstanding the antiquity of this discovery, it does not appear that the Chinese had ever derived from it the advantage of making long voyages.

Homer, in the *Odyssæy*, tells us, that the Greeks employed the loadstone to direct their navigation when they went to besiege Troy; and this aera is nearly the same with that recorded in the Chinese Chronicle. Hence we can no longer doubt, that the direction of the loadstone toward the pole, and even the use of the mariner's compass in navigation, were known to the ancients at least three thousand years ago.

V.

Of the discovery of America, p. 155.

To what I said, p. 155. concerning the discovery of America, a critic of more judgment than the author of *Lettres à un Américain*, has accused me of doing a kind of injury to the memory of so great a man as Christopher Colum-

VOL. IX.

B

bus.

* See l'Extrait des Annales de la China, par Mrs Rouffe and de Guignes.

bus. 'It is confounding,' he remarks, 'Columbus with his sailors, to think that he could believe the sea rose toward the sky, and that they perhaps touched each other on the southern part of the globe.' This criticism is extremely just. I ought to have softened this fact, which I had extracted from some historical relation; for this great navigator, it is to be presumed, must have had very distinct notions concerning the figure of the earth, which he derived both from his own voyages, and from those of the Portuguese to the Cape of Good Hope and the East Indies. It is well known, however, that Columbus, when he arrived at the New Continent, thought himself at no great distance from the east coasts of Asia. As no man, at that period, had circumnavigated the world, he could not know its circumference, and did not imagine that the earth was so extensive as it has been demonstrated by later discoveries. Besides, it must be acknowledged, that this first navigator toward the west, could not fail to be astonished to find, that, when below the Antilles, it was impossible for him to gain the southern regions, and that he was continually forced back. This obstacle still subsists. We cannot, in any season, sail directly from the Antilles to Guiana; because the currents are extremely rapid, and constantly run from Guiana to those islands. Ships sail from Guiana to the Antilles in five or six days; but they require two months to

to return. In order to return, they are obliged to make a large circuit toward the Old Continent, from whence they direct their course toward the Terra Firma of South America. These rapid and perpetual currents from Guiana to the Antilles are so violent that they cannot be surmounted by the aid of the wind; and, as this circumstance is unexampled in the Atlantic ocean, it is not surprising that Columbus, who, notwithstanding all the resources of his genius and knowledge in the art of navigation, could not advance toward the southern regions, should think that something of a very extraordinary nature existed in this place, and perhaps that there was a greater elevation in this part of the sea than in any other; for the currents from Guiana to the Antilles actually run with as much rapidity as if they descended from a height.

The motion of the following rivers, may give rise to the currents from Cayenne to the Antilles.

1. The impetuous river of the Amazons, whose mouth is seventy leagues broad, and its direction more to the North than the South.
2. The river Ouassa is likewise rapid, has the same direction, and its mouth is nearly a league wide.
3. The Oyapok is still more rapid than the Ouassa, passes through a greater tract of land, and its mouth is nearly of the same dimension.

4. The Aprouak has nearly the same extent of course and of mouth as the Ouassa.

5. The river Kaw is less extensive both in its course and mouth; but, though it issues from a Savannah about twenty-five or thirty leagues from the sea, it is extremely rapid.

6. The Oyak, which is a considerable river, divides into two branches at its mouth, and forms the island of Cayenne. This river, at the distance of twenty or twenty-five leagues, receives another called Oraput; it is very impetuous, and derives its source from a mountain of rocks, from whence it descends in rapid torrents.

7. One branch of the Oyak runs, near its mouth, into the river of Cayenne; and these two rivers, when united, are more than a league broad; the other branch exceeds not half a league.

8. The river of Kourou, which is very rapid, and not above half a league wide at the mouth, without reckoning the Macousia, which, though it furnishes much water, comes from no great distance.

9. The Sinamari is an impetuous river; it comes from a great distance, and its bed is pretty narrow.

10. The river Maroni, though it be very rapid, comes from a great distance. Its mouth is more than a league broad, and, next to the Amazon, it discharges the greatest quantity of water.

water. It gives rise to no islands; while the mouths of the Amazon and Oronoko are interspersed with a great number.

11. The rivers of Surinam, of Barbiché, of Essequébé, and some others, till we reach the Oronoko, which is a very large river.

By the accumulations of mud and of earth brought down from the mountains by these rivers, it should appear, all the valleys of this vast continent have been formed; in the middle of the continent there are some mountains, most of which have formerly been volcanoes, and are not sufficiently elevated to allow their summits to be covered with snow or ice.

Hence it is apparent, that the united force of all these rivers gives rise to that general current of the sea from Cayenne, or rather from the Amazon, to the Antilles; and that this general current extends, perhaps, above sixty leagues from the eastern coast of Guiana.

B 3

ADDI

ADDITIONS to the article, Of the Production of Strata, Vol. I. p. 15.

I.

Concerning the Strata in different parts of the Earth.

WE have some examples of quarries and pits of considerable depths, of which the different strata have been examined and described; such as the pit of Amsterdam, which descends 232 feet, and that of Marly-la-ville, which is 100 feet deep. Many other examples might be given, if observers had agreed in their denominations. But some give the name of *marl* to white clay; others apply the term *flint* to round calcareous stones; and others give the denomination of *sand* to calcareous gravel. Hence little advantage can be derived either from their researches or their long dissertations on these subjects; because we are under a perpetual uncertainty with regard to the nature of the substances they describe. We shall, therefore, confine ourselves to the following examples.

An excellent observer has written to one of my friends, in the following terms, concerning the strata in the neighbourhood of Toulon: 'To the north of the city of Toulon,' he remarks, 'there is an immense quantity of stony
' matter,

' matter, which occupies the declivity of the
 ' chain of mountains, and stretches through the
 ' valley from east to west; and one part of it
 ' forms the soil of the valley, and loses itself in
 ' the sea. This stony matter is commonly called
 ' *saffre*; but it is that species of tufa which is
 ' denominated *marga toffacea fistulosa* by natu-
 ' ralists. M. Guettard desired me to furnish
 ' him with all the information I could obtain
 ' concerning this saffre, as well as specimens of
 ' the matter itself, that he might examine it,
 ' and give a detail of its qualities in his me-
 ' moirs. I sent them both; and I believe I have
 ' satisfied him; for he has thanked me for the
 ' information I communicated. He tells me,
 ' that he is to return to Provence and Toulon
 ' in the beginning of May. M. Guet-
 ' tard, however, will probably give us nothing
 ' new upon this subject; for M. de Buffon has
 ' exhausted it in the first volume of his Natural
 ' History, under the article, *Proofs of the theory*
 ' *of the earth*; and it appears, that, in compo-
 ' sing this article, he had in his eye the moun-
 ' tains of Toulon and their ridge.

' At the commencement of this ridge, which
 ' consists of a more or less hard tufa, we
 ' find, in small cavities of the nucleus of the
 ' mountain, quantities of very fine sand, which
 ' are probably the balls mentioned by M.
 ' de Buffon. After breaking other superficial
 ' parts

' parts of the nucleus, we find numbers of sea-
 ' shells incorporated with the stone. I
 ' have several of these shells, the enamel of which
 ' is well preserved. I will send them soon to
 ' M. de Buffon.'

M. Guettard, who has made more observations of this kind than any other naturalist, expresses himself in the following terms, when he treats of the mountains in the neighbourhood of Paris *.

' Below the vegetable soil, which exceeds
 ' not two or three feet, is placed a bed of sand
 ' from four or six to twenty, and often thirty
 ' feet thick. This bed is commonly replete
 ' with stones of the nature of grind-stone.
 ' In some districts, we meet with detached masses of free-stone in this sand bed.

' Below this sand, we find a tufa, from ten
 ' or twelve, to thirty, forty, and even fifty feet
 ' thick. This tufa is not commonly of one equal thickness. It is frequently cut by different strata of spurious or clayey marl, of the
 ' *cos* which the workmen call *tripoli*, or of good
 ' marl, and even by small beds of pretty hard
 ' stones. Under this bed of tufa are
 ' found those which furnish stones for building.
 ' These beds vary in thickness: At first they
 ' exceed not one foot. In some districts, three
 ' or

* Lettre de M. Buffon à M. Guenaud de Montbeillard, Toulon, Avril 16. 1775.

' or four of them lie above each other. They
 ' are succeeded by one of about ten feet, both the
 ' surface and interior parts of which are inter-
 ' spersed with moulds or impressions of shells.
 ' It is followed by another about four feet,
 ' which rests upon one from seven to eight, or
 ' rather upon two of three or four feet. After
 ' these beds, there are several others, which
 ' together form a mass of at least three fathoms.
 ' This mass, after piercing a bed of sand, is suc-
 ' ceeded by clays.

' This bed of sand is earthy and reddish, and
 ' is from two and a half to three feet thick.
 ' After this comes a bed of spurious clay of a
 ' blueish colour; it is a clayey earth mixed with
 ' sand; the thickness of this bed is about two
 ' feet, and is followed by another of five, which
 ' consists of a smooth black clay, the broken
 ' portions of which are nearly as brilliant as jet.
 ' Lastly, this black clay is succeeded by a blue,
 ' which forms a stratum from five to six feet
 ' thick. In these different clays we find pyrites
 ' of a pale yellow colour, and of various fi-
 ' gures. . . The water found below all these
 ' clays prevented us from penetrating any
 ' deeper.'

The strata in the quarries of the district of
 Moxouris, above the suburb of Saint-Marceau,
 are disposed in the following order.

Feet

26 OF THE PRODUCTION

	Feet.	Inches.
' 1. Vegetable soil - - -	1	
' 2. Tufa - - -	12	
' 3. Sand - - -	18	
' 4. Yellowish earth - - -	12	
' 5. Tripoli; that is, a white, fat, compact earth, which hardens when exposed to the sun, and marks any substance in the same manner as chalk	30	
' 6. Flints, or a mixture of greasy sand - - -	12	
' 7. Rock - - -	2	
' 8. A stratum of small stones, from one to two feet - - -	2	
' 9. Two strata of stone, which dissolves by the operation of the air and weather - - -	1	
' 10. Earth and gravel - - -	1	6
' 11. Free-stone - - -	1	6
' 12. Very hard lime-stone - - -	1	
' 13. A greenish stratum - - -	1	6
' 14. A tender calcareous stone, which forms two strata, one of 18 inches, and the other of two feet - - -	3	6
' 15. Several small beds of bastard calcareous stone. They precede the sheet of water common in pits. This sheet the		

diggers.

Feet.

diggers are obliged to remove before they can obtain the potters clay, which lies between two waters *. In all 99

I have given this specimen for want of a better; for the uncertainties with regard to the nature of the different strata are apparent. We cannot, therefore, be too anxious in recommending to observers to be more exact in defining the nature of those materials they attempt to describe. They may at least distinguish them into vitrescent and calcareous, as in the following example.

The soil of Lorrain is divided into two great zones: The eastern, which covers the chain of *Vosges*, which are primitive mountains, composed entirely of vitrifiable and crystalized matters, as granite, porphyry, jasper, and quartz, disposed in detached blocks or groups, and not in regular strata or beds. In all this chain of mountains, there is not the smallest vestige of any marine production; and the hills which proceed from them consist of vitrifiable sand. Where they terminate, and upon a continued bounding line of their descent, the other zone commences, which is totally calcareous, disposed

* Mem. de l'Acad. des Sciences, Année 1756.

fed in horizontal beds, and replete, or rather completely formed, of sea bodies*.

The banks and beds of the earth in Peru are perfectly horizontal, and correspond sometimes at a great distance in different mountains, most of which are two or three hundred fathoms high. They are in general inaccessible, and often as perpendicular as walls, which gives us an opportunity of perceiving the extremities of their horizontal strata. When any of them happens to be round and detached from others, each bed appears like a very flat cylinder, or a section of a cone of no great height. These different beds, placed one above another, and distinguished by their colour and various contours, often resemble a regular and artificial structure. In this country, we see the mountains perpetually assuming the appearance of ancient and sumptuous palaces, of chapels, of castles, and of domes. They are sometimes fortifications composed of long curtains, and defended with bulwarks. After examining these objects, and the correspondence of their strata, we can hardly entertain a doubt, that the circumjacent land has not, at some period, been really sunk. It appears, that those mountains, whose bases were most solidly supported, remained as monuments
to

* Note communicated to M. de Buffon, par M. l'Abbé Bexon, March 15th 1777.

to indicate the height which the soil of these countries anciently possessed *.

The mountain of Birds, called in Arabic *Gebeliter*, is so equal from top to bottom, for the space of half a league, that it rather resembles a wall regularly built by the hands of man, than a rock formed in this manner by the operation of Nature. The Nile washes this mountain a long way; and it is distant from Cairo in Upper Egypt four and a half days journey †.

To these observations, I shall add a remark made by most travellers, that, in Arabia, the soil is of various natures. The region nearest to Mount Libanus presents nothing but broken and overturned rocks, and is called *Arabia Petraea*. The removal of the soil, by the movement of the waters, has rendered this country almost totally barren; whilst the lighter mud, and all the good earth, have been carried to a greater distance, and deposited in that part of the country called *Arabia Felix*. Besides, the *revers* in Arabia Felix, as well as every where else, are more rugged toward the African sea, *i. e.* to the west, than toward the Red sea, which is on the east.

II.

* Bouguer, *figure de la Terre*, p. 89.

† Voyage du P. Vansele.

II.

Of the interior Rock of the Globe.

In p. 179. I remarked, that *solid rocks are often supported by beds of earth, clay, or sand, which have much less specific gravity. This is the case with most hills, and is easily perceived. But, in high mountains, the summits are not only rocks, but these rocks are supported by others; and this structure runs through such an extent of country, where one mountain rises out of another, that it is difficult to determine whether they are founded on earth, or of what nature this earth is. I have seen rocks cut perpendicularly for some hundreds of feet; but these rocks rested upon other rocks, without my being able to perceive where they ended. May we not, however, be allowed to conclude from the less to the greater? Since the rocks of small mountains, the bases of which are visible, rest upon earths less heavy and less solid than stone, is it not reasonable to think, that earth is likewise the basis of high mountains?*

I acknowledge that this conjecture, derived from analogy, is sufficiently founded. The conjecture I then hazarded was written thirty-four years ago. Since that time, I have acquired ideas and collected facts which convince me,
that

that the great mountains composed of vitrescent materials, and produced by the action of the primitive fire, are connected immediately with the interior rock of the globe, which is also a vitreous rock of the same kind. These great mountains are a part of this immense rock, and are only prolongations or eminences formed upon the surface of the globe at the time of its consolidation. Hence we ought to regard them as constituent parts of the original mass of the earth. But the hills or smaller mountains, which rest upon clay or vitrifiable sand, have been formed by the motion and sediments of the waters, at a time long posterior to the formation of the great mountains by the primitive fire *. It is in these points or projections which form the nucleus of mountains, that the veins of metals, though their height be considerable, are

* The internal parts of the primitive mountains which I have penetrated, either in pits or in the galleries of mines, to the depth of twelve and fifteen hundred feet, are entirely composed of *pure vitreous rock*, in which there are slight and irregular fissures, through which the water issues, and vitriolic and metallic solutions. From this fact we may conclude, that the whole nucleus of these mountains is a pure rock, adhering to the primitive mass of the globe. We indeed find, upon their sides, and upon the margins of the valleys, masses of clayey earth, and banks of calcareous stones, at considerable depths. But these are only the remains of those materials which filled up the cavities of the earth, and must be referred to the second epoch of Nature; *Note communicated by M. de Grignon to M. de Buffon, Aug. 6. 1777.*

are not of the highest kind, but of a mean height, and uniformly arranged, i. e. they rise by gradual elevations, and are connected with a considerable chain of mountains, which are occasionally interrupted by valleys.

III.

Of the Vitrification of Calcareous Substances.

In page 184. I said, that *calcareous bodies are alone incapable of being vitrified, and seem to form a distinct class. All other substances may be converted into glass.*

I had not then made those experiments which have since convinced me, that calcareous substances, like all others, may be reduced to glass. To produce this effect, nothing more is necessary than a fire more violent than that of our common furnaces. I reduced lime-stone to glass by a good burning glass. Besides, M. d'Arceet, an able chymist, melted calcareous spar, without the addition of any other matter, by means of a porcelain furnace belonging to M. le Comte de Lauragais. But these operations were performed several years after the publication of my *Theory of the earth*. I knew only that, in the iron furnaces, the light, white, spongy matter, similar to pumice-stone, which issues from them when over-heated, is nothing but

but a vitreous substance, proceeding from the calcareous bodies thrown into the furnace to assist the fusion of the iron-ore. The sole difference between the vitrification of calcareous and vitrescent substances is, that the latter are immediately vitrified by the action of a violent fire alone; but calcareous bodies, before they are vitrified, pass through a state of calcination, and form a line. But, like all other substances, they vitrify, even in our common furnaces, whenever they are mixed with vitrescent matters, especially with those which, like the *aubuë*, or slimy earth, yield most easily to the fire. Hence we may safely conclude, that, in general, every material of which this globe is composed, may be reduced to its primitive state of glass, if a sufficient degree of heat is applied.

ADDITIONS to the article, Concerning Shells, and other Productions of the Sea, found in the interior parts of the Earth, Vol. I. p. 188.

I.

Of Fossil and Petrified Shells.

FROM what I have written, p. 202. on the subject of the Italian letter, in which it is remarked by this author, that *the pilgrims brought from Syria, in the time of the Crusades, those shells peculiar to the Levant, which are now found petrified in France, in Italy, and in other parts of Christendom*, I find that I have not treated M. de Voltaire with sufficient respect. I acknowledge, that I should rather have taken no notice of this opinion, than revived it with a jest, especially as humour is not my talent, and as this is perhaps the only example of pleasantry in all my works. M. de Voltaire is a man whose superiority of genius merits * the highest regard. I was furnished with this letter at the very time I was correcting the sheet which contains the passage in question. I read part of it only, imagining it to be the production of some learned Italian, who, from mere historical knowledge,

* This apology was published in the year 1778.

knowledge, had followed his own prejudices, without consulting Nature; and it was not till after my volume on the Theory of the Earth was printed, that I knew the letter was written by M. de Voltaire. I then sincerely regretted the expressions I had used. This truth I thought it incumbent on me to make public, as well for the sake of M. de Voltaire, as for my own and that of posterity, to whom I would not leave a doubt of the high esteem I have always had for a man of such uncommon talents, and who has done so much honour to human nature and to the age in which he lived.

As the authority of M. de Voltaire made an impression upon some persons, others have endeavoured to discover whether his objection, with regard to the shells found below ground, has any foundation. Upon this subject, I shall subjoin an extract of a memoir which was transmitted to me, and which appears to have been written with that intention.

In traversing the different provinces of France, and even of Italy, 'I every where saw,' le P. Chabenat remarks, 'figured stones; and, in particular places, their number was so great, and they were arranged in such a manner, that it was impossible not to be satisfied, that these parts of the earth had formerly been covered with the sea. I saw shells of every kind, which were perfectly similar both in figure and size to those which now exist. This observation was suffi-

‘cient to convince me, that all these individuals
‘were of different ages, but of the same species.
‘I saw *cornua ammonis* from half an inch to
‘near three feet in diameter. I saw cockles of all
‘sizes, as well as other bivalves and univalves. I
‘likewise saw belemnites, sea mushrooms, &c.

‘The form and number of these figured stones
‘prove, in the most incontestible manner, that
‘they were formerly animals which existed
‘in the ocean. The shells with which the
‘moulds are covered seem to remove every
‘doubt upon this subject; for, in particular spe-
‘cimens, it is equally lustrous, fresh, and natu-
‘ral, as in the living animal. If separated from
‘the mould or nucleus, we could not believe
‘that it was petrified. The same observation is
‘applicable to many other figured stones found
‘in that beautiful and extensive plain, which
‘stretches from Montauban to Toulouse, and
‘from Toulouse to Alby, as well as to the cir-
‘cumjacent places. The whole of this vast plain
‘is covered with vegetable soil from half a foot
‘to two feet thick. Below the soil there is a bed
‘of coarse gravel about two feet in thickness.
‘The gravel is succeeded by a bed of fine sand,
‘which is nearly of an equal thickness; and the
‘rock lies immediately under this bed of sand. I
‘have repeatedly examined the gravel with the
‘greatest attention, and I found it interspersed
‘with an infinite number of figured stones of
‘the

‘ the same form, but of various sizes. I likewise
 ‘ found a number of sea hedge-hogs, and other
 ‘ stones of a regular figure, and perfectly simi-
 ‘ lar. All these facts announce, in language the
 ‘ most expressive, that this country, as well as
 ‘ many others, had formerly been the bottom of
 ‘ the sea, which, by some sudden revolution, had
 ‘ retired, and left its various productions behind.
 ‘ I shall, however, suspend my judgment, on
 ‘ account of M. de Voltaire’s objections, to re-
 ‘ move which, experience and observation must
 ‘ be united.’

Le P. Chabenat next subjoins several experi-
 ments to prove, that the shells found in the earth
 are the same with those which still exist in the
 sea. These experiments I shall not relate, be-
 cause they contain nothing new; and every man
 is satisfied, that fossil and marine shells are pre-
 cisely of the same nature. Le P. Chabenat con-
 cludes his Memoir with remarking, that ‘ all the
 ‘ shells found in the bowels of the earth are un-
 ‘ questionably real shells, and relicks of animals
 ‘ whose element is the ocean, which had former-
 ‘ ly covered these countries; and, consequently,
 ‘ that the objections of M. de Voltaire are ill
 ‘ founded*.’

II.

* Memoir manuscrit sur les pierres figurées, par le P.
 Chabenat. Mountauban, Oct. 8. 1773.

II.

Of the places where Shells are found, p. 204.

TO the enumeration I have given of the great quantities of shells found in all parts of the world, I might add many particular observations which have been communicated to me during these last thirty-four years. I have received letters from the American islands, by which I am assured, that, in almost all of them, shells are found, either petrified or in their natural state, in the interior parts of the earth, and often below the first stratum or vegetable soil. In the Malouine islands, M. de Bougainville found stones which divided into thin plates or leaves, and upon which were impressions of fossil shells, of a species unknown in these seas*. To the same purpose I have letters from several parts of India and of Africa. Don Ulloa informs us†, that, in that district of Chili which extends from Talca Guano to Concepcion, different kinds of shells are found in great numbers, and without any mixture of earth; and that these shells are used to make lime. He adds, that this peculiarity would not be so remarkable, if these shells were found only in low places

* Voyage autour du monde, tom. 1. p. 100.

† Tom. 3. p. 314. de son Voyage.

places which might be covered with the sea. But what is singular, he remarks, that the same heaps of shells are found in the hills at the height of fifty fathoms above the level of the sea. I relate this fact, not because it is singular, but because it corresponds with all the others, and is the only one known to me concerning fossil shells in this part of the world, where I am persuaded that petrified shells will be found as well as every where else, at heights much greater than fifty fathoms above the level of the sea; for the same Don Ulloa has since found petrified shells in the mountains of Peru at the height of above 2000 fathoms; and, according to M. Kalm, shells are seen in North America upon the tops of several hills: He tells us, that he saw them on the summit of the Blue Mountains. They have also been found in the chalk quarries near Montreal, in certain stones near Lake Champlain in Canada *, and in the most northern regions of this New Continent; for the Greenlanders believe, that the world had been drowned by a deluge, and, in evidence of this event, they quote the shells and the bones of whales which cover the most elevated mountains of their country †.

If from this we pass to Siberia, we shall find the same proof, of the ancient abode of the ocean

* Mem. de l'Acad. des Sciences, année 1752, p. 194.

† Voyage de M. Crantz; *Hist. gen. des voyages*, tom. 19. p. 105.

ocean upon all our Continents. Near the mountain Jeniseik, there are other mountains less elevated, upon the summits of which we find heaps of shells well preserved both in figure and natural colours. These shells are all empty, and some of them fall into powder as soon as they are touched. *The sea of this country produces no shells similar to those found on the tops of mountains.* The largest of these shells exceed not an inch in breadth, and others are very small*.

But I can exhibit facts which are still more obvious. Every man, in his own province, has only to open his eyes, and he will see shells in all places where lime-stone is found, as also in most clays, though, in general, marine productions are more rare in clays than in calcareous substances.

In the territory of Dunkirk, on the top of the mountain of the Recollets, near that of Cassel, and at 400 feet above the level of the sea, there is a horizontal stratum of shells, which are so closely packed together that most of them are broken. Above this stratum, there is a bed of earth from seven to eight feet deep. These shells are situated at the distance of six leagues from the sea, and they are of the same species with those found on its coast†.

In

* Relation de Mess. Gmelin et Muller; *Hist. gen. des voyages*, tom. 18. p. 342.

† Mem. pour la subdelegation de Dunkerque, relativement à l'Histoire naturelle de ce canton.

PRODUCTIONS OF THE SEA. 41

In Mount Gannelon, near Anet, and at some distance from Compiègne, there are several quarries of excellent lime-stone. Between the different strata of the lime-stone we find gravel mixed with an infinite number of sea-shells, or portions of shells, which are very light and friable. In the same place, there are common oyster-shells in fine preservation, and extend more than a league and a quarter in length. In one of these quarries, there are three strata of shells in different states. In two of these strata, they are so much broke, that their species cannot be distinguished: But, in the third, there are oysters, which have suffered no alteration, but that of being excessively dried. The nature, figure, and enamel of the shells, are the same as in the live animals. These shells have acquired a great lightness, and easily exfoliate. The lime-stone quarries are situated at the foot of the mountain, and have a small declivity. In descending towards the plain, we find oysters, which are neither dried nor have undergone any change, but have the same weight, and the same enamel with those which are daily taken out of the sea *.

In the neighbourhood of Paris, these marine shells are not less common. The marl pits of Bougival furnish a kind of middle-sized

* Extrait d'une Lettre de M. Lefchevin à M. de Buffon; *Compiègne, Oct. 8. 1772.*

fized oysters. They are not entire, but cut in different directions, and finely polished. Near Belleville, where free-stone is quarried, we find a mass of sand in the earth, which contains branched bodies, which may have been corals or madrepores converted into stone. These marine bodies are not in the sand alone, but in the stones, which likewise contain shells of different kinds, as volutes, univalves, and bivalves *.

Switzerland is not less abundant in fossil marine bodies than France and the other countries we have mentioned. In Mount Pilate, in the canton of Lucerne, we find petrified sea-shells, and the bodies and relicks of fishes. In the same mountain, there are corals, and slates which easily exfoliate, and, between the leaves, a fish is generally found. Some years ago, the jaws, and even entire heads of fishes, together with their teeth, were discovered †.

M. Altman remarks, that, in one of the highest parts of the Alps, near Grindelvald, where the famous glaciers (Gletschers) are formed, there are fine marble quarries, which he has represented in one of the engravings of these mountains. The marble quarries are only a few paces distant from the glacier. The marble

* Mem. de M. Guettard; *Acad. des Sciences*, année 1764, p. 492.

† Promenade au Mont Pilate; *Journal étranger*, mois de Mars, 1756.

ble is of various colours, as white, yellow, jasper, red, and green. The marble is drawn on sledges above the snow as far as Underseen, where they are embarked to be carried to Berne by lake Thorne, and afterwards by the river Are*. Thus marble and calcareous stones are found, at great heights, in this part of the Alps.

M. Cappellet, in making researches on Mount Grimfel, one of the Alps, has remarked, that the hills and smaller mountains which limit the valleys, are mostly composed of free-stone, of a grain more or less fine and close. The tops of these mountains generally consist of limestone, of various colours and hardness. The mountains more elevated than these calcareous rocks, are composed of granite and other stones, which appear to be of the nature of granite and of emery. It is in these granity stones that rock-crystal begins to be formed. But, in the limestone rocks below, we find nothing but spar and calcareous concretions. In general, it has been remarked, concerning shells of every kind, whether fossil or petrified, that certain species are always found together, and that others are never met with in these places. The same thing happens in the ocean, where particular species of testaceous animals are constantly found together,

* Essai de la description des Alpes glaciales, par M. Altman.

ther, in the same manner as certain plants always grow together on the surface of the earth*.

It has been too generally believed, that, there are no shells, or other productions of the sea, on the highest mountains. It is true, that there are several summits, and a great number of peaks, which are entirely composed of granite and vitrifiable rocks, and in which no mixture can be perceived. These contain neither the moulds of shells, nor the relicks of any marine bodies. But there is a much greater number of mountains, and some of them very high, where these relicks are to be found. M. Costa, professor of anatomy and botany in the university of Perpignan, in the year 1774, discovered, some fathoms below the top of Mount Nas, situated in the middle of the Spanish Cerdagne, and one of the most elevated parts of the Pyrennees, a great number of lenticular stones, *i. e.* blocks composed of lenticular stones, and these blocks were of different figures and different sizes; the largest might weigh from forty to fifty pounds. He remarked, that the part of the mountain where these lenticular stones were found, seemed to have formerly sunk; for, in this place, he saw an irregular, oblique depression, very much inclined to the horizon; and one of its extremities respected the top, and the other the bottom of the

* Lettres philosophiques de M. Bourguet, *Biblioth. raisonnée, mois d'Avril, Mai, et Juin, 1730.*

the mountain. He could not distinctly perceive the dimensions of this depression, because most of it was covered with snow, though it was the month of August. The banks of rocks which surrounded these lenticular stones, as well as those immediately below, are calcareous for more than a hundred fathoms. This Mount Nas, to judge of it by the eye, seems to be as high as Canigou, and presents no vestige of a volcano.

A thousand other examples of marine shells, found in an infinity of places, as well in France as in different parts of Europe, might be given. But such an enumeration of particular facts, which are already too much multiplied, would swell this work, without answering any useful purpose. From the whole, however, we cannot refrain from drawing this obvious conclusion, that all the inhabited parts of the earth have formerly, and during a very long course of time, been covered with the waters of the ocean.

I shall only remark, that these sea-shells are found in different states. Some of them are petrifications, or stones moulded into the form of shells; and others are in the same state as they still exist in the ocean. The quantity of petrified shells, which are nothing but stones figured by shells, is infinitely greater than that of fossil shells, and they are never found together,

ther, nor even in places contiguous ; it is only in the neighbourhood, and some leagues distant from the sea, that we find beds of shells in their natural state, and these are commonly the same with those which exist in the adjacent seas. Petrified shells, on the contrary, are found, almost every where, at great distances from the sea, and on the highest hills, many species of which belong not to our seas, and several of them have no existing representatives ; such as those ancient species we formerly mentioned, which only existed when the globe was much warmer. Of more than a hundred species of *cornua ammonis*, remarks one of our learned Academicians, with which we are acquainted, and which are found in the environs of Paris, of Rouen, of Dive, of Langres, and of Lyons, as well as in the Cevernes, in Provence, in Poitou, in Britain, in Spain, and in other countries of Europe, there is but one species, called the *Nautilus papyraceus*, found in our seas, and five or six others produced in foreign seas *.

III.

* Mem. de l'Acad. des Sciences, année 1722, p. 242.

III.

Of those great Volutes called Cornua Ammonis, and of some large bones of terrestrial animals.

IN p. 211. I said, *That many shell-fishes inhabit the deepest parts of the ocean, and are never thrown upon the coasts; authors have, therefore, termed them Pelasgie, to distinguish them from the other kinds, which they call Littorales. It is probable that the cornu ammonis, and some other species found only in a petrified state, belong to the former, and that they have been impregnated with stony matter in the very places where they are discovered. It is also probable, that the species of some animals have been extinguished, and that these shells may be ranked among this number. The extraordinary fossil bones found in Siberia, in Canada, in Ireland, and several other places, seem to confirm this conjecture; for no animal has hitherto been discovered to whom bones of such enormous size could possibly belong.*

Upon this passage I have to make two important remarks:

- i. That these cornua ammonis, which are so different from each other both in figure and size,

size, seem to form rather a genus than a species in the class of shell animals, are really the relicks of so many species which have perished, and no longer subsist. I have seen some of them so small, that they exceed not a line, and others so large that they were more than three feet in diameter. Observers worthy of credit have assured me, that that they have seen some still larger, and particularly one of eight feet in diameter, and one foot thick. These different *cornua ammonis* seem to form distinct species. Some of them are more or less fluted. They are all spiral; but they terminate differently, both at their centres and at their extremities. These animals, formerly so numerous, are no longer found in any of our seas. They are known to us by their relicks only; and the immensity of their number cannot be better represented than by an example which I have daily before my eyes. In the iron mine near Etivey, (three leagues from my forge of Buffon), which has been wrought 150 years, and has supplied the iron works of Aisy during all that time, there are such quantities of *cornua ammonis*, entire and in fragments, that the greatest part of the ore seems to have been moulded in these shells. The mine of Conflans in Lorrain, which supplies the furnace of Saint Loup in Franche-comte, is likewise entirely composed of belemnites and *cornua ammonis*. These last ferruginous

nous shells are so different in size, that they weigh from a drachm to two hundred pounds *. Other places might be mentioned where they equally abound. In the same manner, we find belemnites, lenticular stones, and moulds of many other shells, which now no longer exist in any part of the ocean, though they are almost universally diffused over the surface of the earth. I am persuaded that all these lost species formerly subsisted during the time that the temperature of the earth and waters was warmer than it is at present; and that, in proportion as the globe cools, other species, which now exist, will perish like the former, for want of heat sufficient to support them.

2. That some of those enormous bones, which I thought had belonged to unknown animals, whose species was supposed to be lost, have, nevertheless, after the most accurate examination, appeared to belong to the elephant and hippopotamus, but to species of these animals much larger than those which now exist. Of land-animals I know only one species which is lost; and it is that of the animals whose grinding teeth, with their just dimensions, are represented in plates I. II. III. The other large teeth and bones which I have collected belonged to the elephant and hippopotamus.

VOL. IX.

D

ADDI-

* Mem. de physique de M. Grignon, p. 378.

ADDITIONS to the Article, Of the Inequalities of the surface of the Earth, Vol. I, p. 228.

I.

Of the height of Mountains.

WE remarked, p. 237. that *the highest mountains in the world are the Cordeliers of America, and especially that part of them which lies under the Equator, or between the Tropics.* Our mathematicians who were sent to Peru, as well as some other travellers, have measured the height of these mountains above the level of the South Sea. Some of them were measured geometrically, and others by the barometer, which, being subject to little variation in that climate, gives the heights nearly as exact as a geometrical measurement. The following are the results of their observations.

Heights of the most elevated mountains of the Province of Quito in Peru.

	Fathoms.
Cota-catché, to the north of Quito	2570
Cayambé-orcou, under the Equator	3030
Pitchincha,	

THE EARTH'S SURFACE. 51

	Fathoms.
Pitchincha, a volcano in 1539, 1577, and 1660	2430
Antifana, a volcano in 1590	3020
Sinchoulogoa, a volcano in 1660	2570
Illinica, supposed to be a volcano	2717
Coto-paxi, a volcano in 1533, 1742, and 1744	2950
Chinboraço, a volcano; the date of its eruption unknown	3220
Cargavi-raso, a volcano in 1698	2450
Tongouragoa, a volcano in 1641	2620
El-altan, one of the mountains called Coil-lanes	2730
Sanguai, a volcano which has burnt since the year 1728	2680

By comparing the heights of the mountains of South America with those of our Continent, we will perceive that, in general, they are one fourth part higher than the mountains of Europe, and that almost the whole of them have been and actually are volcano's. But even the highest mountains in the interior parts of Europe, Asia, and Africa, have been extinguished long beyond the record of history. It is true, that, in several of these last mountains, we evidently recognise the ancient existence of volcano's, as well by the black and burnt sides of precipices, as by the nature of the matters which surround them,

and which extend along the ridges of the mountains. But, as these mountains are situated in the interior parts of Continents, and now very distant from the sea, the action of the subterraneous fires, which cannot produce great effects but by the shock of water, ceased after the seas retired. It is for this reason, that, in the Cordeliers, whose roots may be said to border upon the South Sea, most of the peaks are actual volcano's; whilst the volcano's of Auvergne, Vivarais, Languedoc, Germany, Switzerland, &c. in Europe, and those of Mount Ararat in Asia, and of Mount Atlas in Africa, have long been absolutely extinct.

The height at which vapours freeze is about 2400 fathoms in the Torrid Zone, and about 1500 in France. The tops of high mountains sometimes surpass this line from 800 to 900 fathoms, and all this space is covered with snow which never melts. The highest clouds rise not above 300 or 400 fathoms above these mountains, and consequently exceed the level of the sea about 3600 fathoms. Hence, if the mountains were still higher, we should see, in the Torrid Zone, a belt of snow commencing at 2400 fathoms above the level of the sea, and terminating at 3500 or 3600 fathoms, not on account of the cessation of the cold, which augments in proportion to the elevation, but because the vapours would not rise higher *.

M.

THE EARTH'S SURFACE. 53

M. de Keralio, a learned philosopher, has collected the heights of the mountains in several countries, from the measurements of different persons.

In Greece, M. Bernoulli determined the height of Mount Olympus to be 1017 fathoms. Hence the snow cannot lie upon it perpetually; neither can snow lie constantly on Pelion in Thessaly, nor on Cathalylium and Cyllene; because the height of these mountains does not rise to the freezing degree. M. Bougnier assigns 2500 fathoms as the height of the Peak of Teneriff, the top of which is always covered with snow. Mount Ætna, the Norwegian Mountains, the Hemus, the Athos, the Atlas, the Caucasus, and several others, such as Mounts Ararat, Taurus, and Libanus, are perpetually covered with snow, near their summits.

Fathoms.

Pontoppidan informs us, that the highest mountains of Norway are 3000

Note. This measure, as well as the following, appears to be exaggerated.

According to M. Brovallius, the highest mountains of Sweden are - 2333

The following, according to the Memoirs of the Academy of Sciences, are the highest mountains of France.

Le Cantal	-	-	-	984
Mount Ventoux	-	-	-	1036
			D 3	Le

54 INEQUALITIES UPON

	Fathoms.
Le Canigou of the Pyrennees -	1441
Le Mouffec -	1253
Le Saint-Barthélemy -	1184
The Mountain of Gold in Auvergne, an extinguished volcano -	1048
According to Mr Needham, the height of the mountains of Savoy are,	
The Convent of St Bernard	1241
The Rock to the south of St Bernard	1274
Mount Serène -	1282
L'Allée Blanche -	1249
Mount Tournè -	1683
According to M. Facio de Duiller, Mount Blanc, or the Cursed Mountain, is	2213

It is certain, that the chief mountains of Switzerland are higher than those of France, Spain, Italy, and Germany. Several learned men have ascertained the height of these mountains.

The greatest part of these mountains, according to M. Mikhéli, as the Wetter-horn, the Schreck-horn, the Eigheff-Schneeberg, the Fisher-horn, the Stroubel, the Fourke, the Louk-marier, the Crispalt, the Mougles, the ridge of Baduts and Gottard, are from 2400 to 2750 fathoms above the level of the sea. But these measures, I suspect, are too high, especially as they exceed, by one half, those given by Cassini, Scheuthzer, and Mariotte, which may be estimated too low, but not to this extent. My suspicion is farther confirmed, by considering that, both in
the

the cold and temperate regions, where the air is always troubled with storms, the barometer is subject to so great variations, that its results cannot be trusted.

II.

Of the Direction of Mountains.

In vol. I. p. 240. I remarked, that *the direction of the great mountains of America is from north to south, and that those of the Old Continent run from west to east.* This last assertion requires to be modified; for though, at first sight, we may follow the mountains as far as China, by passing from the Pyrennees in Auvergne, to the Alps in Germany, and in Macedonia, to Caucasus and other mountains of Asia, as far as the Tartarian sea; and though Mount Atlas, in the same manner, appears to traverse the Continent of Africa from west to east, the middle of this vast peninsula may still consist of a chain of high mountains stretching from Mount Atlas to the Mountains of the Moon, and from these to the Cape of Good Hope: In this view, the middle of the Continent of Africa may be considered as consisting of mountains which run from north to south through its whole extent, like the mountains

tains of America. Those parts of Mount Atlas which traverse Africa from west to east, should be considered as branches only of the principal chain. The mountains of the Moon, which run from west to east, may likewise be regarded as collateral branches; and, if there are no volcano's in this prodigious range of mountains, it may be owing to the vast distance of the sea from the middle regions of Africa; whilst, in America, the sea is very near the foot of the high mountains, which, instead of occupying the middle of the peninsula of South America, are all situated to the west; and the extensive low lands are entirely on the east side.

The great chain of the Cordeliers are not the only mountains of America which run from north to south. In the territory of Guiana, about one hundred and fifty leagues from Cayenne, there is a chain of pretty high mountains, which also extends from north to south. On the Cayenne side, this chain is so steep, that these mountains are almost inaccessible. This steepness seems to indicate, that, on the other side, the declivity is gentle, and consists of fine land. The tradition of the country, accordingly, or rather the testimony of the Spaniards, is, that, beyond the mountains, there are populous nations of savages united into regular societies. It is likewise said, that there is a gold mine in these mountains, and a lake in which grains of gold

gold are found: But this fact requires confirmation.

In Europe, the chain of mountains which begins in Spain, and passes through France, Germany, and Hungary, divides into two great branches, one of which extends into Asia by the mountains of Macedonia, Caucasus, &c. and the other branch stretches from Hungary into Poland and Russia, and extends as far as the sources of the Wolga and Boristhenes; and, stretching still farther, it joins another chain in Siberia, and terminates in the north sea to the west of the river Oby. These chains of mountains ought to be regarded as one continued ridge, from which several large rivers derive their sources: Some of these rivers, as the Tagus, and the Doura in Spain, the Garonne and the Loire in France, and the Rhine in Germany, empty themselves into the ocean; others, as the Oder, the Vistula, and the Niemen, fall into the Baltic sea; others, as the Dwina, fall into the White sea, and the river Petzora empties itself into the Frozen sea. On the east side, this chain of mountains gives rise to the Yeucar and Ebre in Spain, to the Rhone in France, and to the Po in Italy, which fall into the Mediterranean; to the Danube and Don, which lose themselves in the Black Sea; and, lastly, to the Wolga, which falls into the Caspian.

Norway

Norway is full of rocks and groups of mountains. There are plains, however, which extend, without interruption, six, eight, and ten miles. Their direction is not from west to east, like that of the other European mountains. On the contrary, they stretch, like the Cordeliers, from south to north*.

In the south of Asia, from the island of Ceylon to Cape Comorin, there is a chain of mountains which separates Malabar from Coromandel, traverses the Mogul country, joins Mount Caucasus, stretches through the country of the Calmucks, and terminates in the North Sea to the east of the Irtis. Another chain extends from north to south as far as Razatgat in Arabia, and may be traced, at some distance from the Dead Sea, as far as Jerusalem: It surrounds the extremity of the Mediterranean, and the point of the Black Sea, from which it traverses Russia, and terminates in the North Sea.

We may likewise remark, that the mountains of Indostan and those of Siam run from south to north, and both unite with the rocks of Thibet and Tartary. Each side of these mountains presents a different season: On the west, they have six months of rain, while, on the east, they enjoy the finest weather †.

All

* Hist. Nat. de Norwege, par Pontoppidan. *Journal étranger*, mois d'Avout, 1755.

† Hist. Phil. et Polit. tom. 2. p. 46.

All the mountains of Switzerland, as those of the Vallese and the Grisons, those of Savoy, Piedmont, and Tirol, form a chain, which extends, from north to south, as far as the Mediterranean. Mount Pelate, which is situated in the centre of Lucerne, nearly in the centre of Switzerland, forms a chain of about fourteen leagues, extending from north to south as far as the canton of Bern.

We may, therefore, conclude in general, that the greatest eminences of this globe are situated from north to south, and that those which run in other directions ought to be regarded as collateral branches only of these primitive mountains: And, it is partly by this disposition of the primitive mountains, that all the points or terminations of continents are either south or north; as appears from the points of Africa, of America, of California, of Groenland, of Cape Comorin, of Sumatra, of New Holland, &c. This fact seems to prove, as formerly remarked, that the waters have proceeded in greater quantities from the south than from the north pole.

If we consult a new map of the world, in which are represented, round the Arctic Pole, all the lands of the four quarters of the globe, except the north point of America, and, round the Antarctic Pole, all the seas, and the small portions of land to be found in the southern hemisphere, we shall evidently perceive, that
many

many more revolutions have happened in the latter than in the former hemisphere, and that the quantity of water has always been, and still is, much greater there than in our hemisphere. Every thing concurs in proving, that the greatest inequalities of the globe exist in the southern regions, and that the general direction of the primitive mountains is from north to south, rather than from east to west, through the whole extent of the earth's surface.

III.

Of the formation of Mountains.

ALL the valleys and dales on the surface of the globe, as well as all the mountains and hills, have originated from two causes, namely, fire and water. When the earth first assumed its consistence, a number of inequalities took place on its surface; swellings and blisters arose, as happens in a block of glass or of melted metal. Hence this first cause produced the original and the highest mountains, which rest on the interior rock of the earth as their base, and below which, as every where else, there must have been vast caverns, which sunk in at different periods. But, without considering this second event,

event, the falling in of the caverns, it is certain, that, when the earth first consolidated, it was every where furrowed with depths and eminences, which were produced solely by the action of cooling. Afterwards, when the waters were precipitated from the atmosphere, which happened when the earth cooled so much as to be unable to repel the vapours, these waters covered the whole surface of the globe to the height of two thousand fathoms; and, during their long abode upon our continents, the motion of the tides and that of the currents, changed the disposition of the primitive mountains and valleys. These movements would form hills in the valleys, and would cover the bottoms and knaps of the mountains with new beds of earth; and the currents would produce furrows or valleys with corresponding angles. It is to these two causes, of which the one is much more ancient than the other, that the present external form of the surface of the earth is to be referred. Afterwards, when the seas sunk down, they produced those steep precipices on the west, where they ran with the greatest rapidity, and left gentle declivities on the east.

The structure of those eminences which were formed by the sediments of the ocean, is very different from that of those which owe their origin to the primitive fire. The first are disposed in horizontal beds, and contain an infinite

nite number of marine productions. The second, on the contrary, are less regular in their structure, and include no marks of sea-bodies. These mountains of the first and second formation, have nothing in common but the perpendicular fissures; but these fissures are effected by two different causes. The vitrescent matters, in cooling, diminished in size, and, of course, they split, and receded to different distances. But those composed of calcarious matters transported by the waters, split into fissures solely by drying.

I have often remarked, that, in detached hills, the first effect of the rains is gradually to carry down from the summit the earth and other bodies, which form at the foot a pretty thick stratum of good soil, while the top is left entirely bare. This effect is, and necessarily must be, produced by the rains. But a previous cause disposed these and similar matters round all hills, not excepting those which are detached; for, on one side, the earth is uniformly better than on the other: The hills are always steep and precipitant on one side, and have a gentle declivity on the other; which proves clearly that the action, as well as the direction of the motion of the waters, were greater on one side than on the other.

IV.

Of the Density which certain matters acquire by Fire, as well as by Water.

IN p. 246, I said, that the hard points found in free-stone consisted of metallic matter, which appeared to have been melted by a strong fire. This assertion seems to insinuate that the great masses of free-stone have originated from the action of the primitive fire. I at first imagined that this matter owed its density and the adhesion of its particles solely to the intervention of water. But I have since learned that the action of fire produces the same effect; and I shall relate some experiments which at first surprised me, but which I have repeated so often as to remove every doubt upon this subject.

EXPERIMENTS.

I pounded free-stones of different degrees of hardness, till they were reduced to a powder more or less fine. These powders I employed to cover the cements I used in converting iron into steel. This powder of free-stone was strewed over the cement, and heaped up, in the
form

form of a dome of three or four inches in thickness, on an earthen vessel of three feet long by two broad. After undergoing the action of the fire in my blast furnaces, during several days and nights without interruption, it was no longer the powder of free-stone, but a mass so solid that we were obliged to break it in order to uncover the vessel which contained the iron, now converted into steel. The action of fire upon this powder of free-stone produced masses equally solid as free-stone of a middling quality, which does not ring under the hammer. This fact showed that fire, as well as water, could prove a cement to vitrifiable sand, and, consequently, might have formed those immense masses of free-stone which compose the nucleus of some of our mountains.

I am, therefore, fully persuaded, that all the vitrescent matters, of which the interior rock of the globe, as well as the nuclei of great mountains, are composed, have been produced by the action of the primitive fire; and that the waters have only formed those accessory strata which surround these nuclei, which are all parallel and horizontal, or equally inclined, and in which we find the relicks of shells and other productions of the ocean.

In the formation of free-stone and other vitrescent matters, I pretend not to exclude the intervention of water. On the contrary, I am inclined

inclined to believe, that vitrifiable sand may acquire consistence, and unite into masses more or less hard, perhaps more easily by means of water than by the action of fire. I have related the above facts solely with the view of preventing objections which would not fail to be made, if it had been thought that I attributed the solidity of free-stones, and other bodies composed of vitrifiable sand, to the intervention of water alone. It is certain, that all the free-stone found on the surface, or at inconsiderable depths, have been formed by water; for, on the surface of these masses of free-stone, we perceive marks of undulations and rollings, and sometimes the impressions of plants and shells. But the free-stones formed by the sediments of water are easily distinguished from those which have been produced by fire. The latter have a coarser grain, and crumble down more easily than free-stone cemented by the intervention of water, which is more compact, and harder than that whose particles have been united by the action of fire.

Ferruginous matters assume a great degree of hardness by fire; for nothing is harder than cast iron. But ferruginous bodies may likewise acquire considerable density by the intervention of water. Of this fact I was ascertained by putting a quantity of filings of iron into vessels exposed to the rain. These filings formed a mass

so hard, that it could only be broken by the hammer.

The vitreous rock which composes the interior mass of the globe, is harder than common glass. But it is not harder than certain volcanic lavas, and much softer than cast iron, which, however, is only glass mixed with ferruginous particles. This great hardness of the interior rock shows that it consists of the most fixed particles of matter, and that, from the time of their consolidation, they assumed the consistence and hardness which they still possess. Hence it cannot be objected to my hypothesis of general vitrification, that bodies reduced to glass by our furnaces are less hard than the rock of the globe; since cast iron, some lavas, or basalts, and even certain porcelains, are harder than this rock, and yet they derive their hardness from the action of fire alone. Besides, the elements of iron and other minerals which give hardness to matters liquified by fire, or attenuated by water, existed, as well as the fixed earth, from the time that the globe was first consolidated: And I have already remarked, that the interior rock ought not to be regarded as pure glass, similar to that we make with sand and salts, but as a vitreous product mixed with matters the most fixed, and most capable of supporting the great and long continued action of the primitive fire, the great effects of which can only be compared
in

in a very distant manner with the inconsiderable operations of our furnaces; and yet, from this comparison, though unfavourable, we clearly perceive what effects are common to the primitive fire and to our furnaces; and it shows, at the same time, that the degree of hardness depends less on the degree of heat than on the combination of matters submitted to its action.

V.

Of the inclination of the Strata in the Mountains.

I remarked, in Vol. I. p. 15. that, in plains, the strata are exactly horizontal. It is in the mountains only that they are inclined to the horizon; because they have originally been formed by sediments deposited upon an inclined base.

The beds of calcarious matters are not only horizontal in the plains, but likewise in all mountains which have not been disturbed by earthquakes or other accidental causes: And, when the strata are inclined, the whole mountain is likewise inclined, and has been forced into that position by a subterraneous explosion, or by the sinking of a part of the earth, which had served it as a basis. We may therefore conclude, in general, that all strata formed by the sediments of water are horizontal, like the

water itself, except those which have been formed on an inclined base, as is the case with the most part of coal-mines.

The most external part of the earth, whether in plains or mountains, is solely composed of vegetable earth, which owes its origin to sediments of the air, of vapours, and of dews, and to the successive destruction of herbs, leaves, and other parts of decomposed plants. This first stratum every where follows the declivities and curvatures of the earth, and is more or less thick according to particular local circumstances *. The vegetable stratum is commonly much thicker in valleys than on hills; and its formation is posterior to that of the primitive strata of the globe, the most ancient and most internal, of which have been formed by fire, and the newest and most external have derived their origin from matters transported and deposited in the form

* On the tops of some mountains, the surface is absolutely naked, and presents nothing to the view but pure rock, or granite, without any vegetation, except in the small fissures, where the wind has transported sand, and collected the particles of earth which float in the air. At some distance from the last branch of the Nile, there is a mountain composed of granite, of porphyry, and of jasper, which extends more than twenty leagues in length, by perhaps an equal number in breadth. The surface of the summit of this enormous quarry, we are assured, is absolutely devoid of vegetables, and forms a vast desert, where neither quadrupeds, nor birds, nor even insects, can exist. But exceptions of this kind, which are particular and local, merit no consideration.

form of sediments by the motion of the waters. These, in general, are horizontal; and it is only by the action of particular causes that they sometimes appear inclined. The beds of calcarious stones are commonly horizontal, or slightly inclined; and, of all calcarious substances, the beds of chalk preserve their horizontal position most exactly. As chalk is only the dust of decayed calcarious bodies, it has been deposited by waters whose movements were tranquil, and their oscillations regular; whilst the matters which were only broken into large masses, have been transported by currents, and deposited by the removal of the waters; which is the reason why their strata are not so perfectly horizontal as those of chalk. The high coasts of Normandy are composed of horizontal strata of chalk so regularly perpendicular, that, at a distance, they have the appearance of fortified walls. Between the strata of chalk there are small beds of black flint, which give rise to the black veins in white marble.

Beside the calcarious shells, the strata of which are slightly inclined, and whose position has never been changed, there are many others which have been deranged by different accidents, and which are all much inclined. Of these there are many examples in various parts of the Pyrennees, some of which are inclined forty-five, fifty, and even sixty degrees below the horizon-

tal line. This circumstance seems to prove, that great changes have been produced in these mountains by the sinking of subterraneous caverns which had formerly supported them.

VI.

Of the Peaks of Mountains.

I endeavoured to explain, Vol. I. p. 247. how the peaks of mountains had been deprived of the vitrifiable sands with which they had been originally invested; and my explanation errs in this circumstance only, that I attributed the first formation of the rocks which form the nuclei of these peaks to the intervention of water, instead of ascribing it to the action of fire. These peaks or horns of mountains are nothing but prolongations of the interior rock of the globe, which were environed with great quantities of scoriae and dust of glass. These loose materials must have been carried down by the movement of the sea, when it made its retreat. Afterwards, the rains and torrents of water would soon deprive the masses of pure rock of all their coverings, and make them completely bare, as they are at present. I may remark, in general, that no other change falls to be made in my theory of the earth than the following fact, that

that the first mountains derived their origin from the primitive fire, and not from the intervention of water, as I had conjectured; because I had then been induced to believe, by the authority of Woodward and some other naturalists, that shells were found on the tops of all mountains. But, from more recent observations, it appears, that there are no shells on the highest summits, nor above two thousand fathoms above the level of the sea. Hence the waters have never surmounted those high summits, or at least have remained but a short time upon them; so that they have formed only the hills and the calcareous mountains, which never rise to the height of two thousand fathoms.

ADDI-

ADDITIONS to the article, Of Rivers,
Vol. I. p. 251.

Additional Observations on the Theory of running Waters.

PAGE 266. Concerning the theory of running waters, I have to add a new observation which I made since I established mills, by which the different celerities of water may be pretty accurately ascertained. These mills are composed of nine wheels, some of which are impelled by a fall of water of two or three feet, and others by a fall of five or six feet high: I was at first surprised to find, that all the wheels turned more quickly in the night than in the day, and that the difference was greater in proportion to the height and breadth of the column of water. For example, if the water falls six feet, the wheel will turn a tenth, and sometimes a ninth quicker in the night than in the day; and, if the fall is less high, the difference of celerity will likewise be less; but, it is always so sensible as to be easily recog-

recognised. I ascertained this fact by placing white marks upon the wheels, and reckoning the number of revolutions in equal times, both during the day and the night ; and I uniformly found, by a great number of observations, that the time when the wheels moved with the greatest celerity was the coldest hour of the night, and that they moved slowest when the heat of the day was greatest. In the same manner, I afterwards found, that the celerity of all the wheels is greater in winter than in summer. These facts, which have escaped the observation of philosophers, are of importance in practice. The theory of them is extremely simple : This augmentation of celerity depends solely on the density of the water, which is increased by cold and diminished by heat : And, as the same volume of water only can pass by the trough, this volume, which is denser in winter and during the night, than in summer or in the day, acts with more force on the wheel, and, of course, communicates to it a greater quantity of motion. Thus, *caeteris paribus*, there will be less loss of water, if we stop the machines during the heat of the day, and work them during the night. By observing this method in my forges, its influence in the process of making iron amounted to one twelfth part.

Another observation merits attention : Of two wheels, the one nearer the canal than the other,
but

but perfectly equal in every other respect, and both moved by an equal quantity of water, the wheel nearest the canal moves quicker than the one more remote, and to which the water cannot arrive till after it has run over a certain space in the particular runner that terminates in this wheel. It is well known, that the friction of water on the sides of a canal diminishes its celerity. But this circumstance is not sufficient to account for the considerable difference in the motion of these two wheels. It is owing, in the *first* place, to the water in this canal not being pressed laterally, as it is when it enters by the trough of the canal, and to its striking immediately the ladles of the wheel. *Secondly*, This inequality of motion, depending on the distance of the wheels from the canal, is likewise owing to the water, which passes through a trough, not being a column of equal dimensions with the trough; for the water, in its passage, forms an irregular cone, which is depressed on the sides in proportion to the breadth of the volume of water in the canal. If the ladles of the wheel are very near the trough, the water acts very near as high as the aperture of the trough: But, if the wheel is more distant from the canal, the water sinks in the runner, and strikes not the ladles of the wheel at the same height, nor with equal celerity, as in the first case. The union of these two causes produces that

that diminution of celerity in wheels which are distant from the canal.

II.

Of the saltness of the Sea, p. 275.

ON this subject there are two opinions, and both of them are partly true. Halley attributes the saltness of the sea solely to the salts of the earth carried down by the rivers; and even supposes that the antiquity of the world may be discovered by the degree of saltness in the waters of the ocean. Leibnitz, on the contrary, believes, that the globe having been liquified by fire, the salts and other empyreumatic substances produced with the aqueous vapours a salt lixivium, and, consequently, that the sea received its saltness from the beginning. The opinions of these two great philosophers, though opposite, should be united, and may even coincide with my own. It is extremely probable, that, at the beginning, the action of fire combined with that of water dissolved all the saline substances on the surface of the earth; and, of course, that the first degree of saltness in the sea proceeded from the cause assigned by Leibnitz; but this prevents not the second cause assigned by Halley from having considerable

considerable influence upon the actual degree of saltiness in the sea, which must always augment, because the rivers incessantly carry down great quantities of fixed salts, which cannot be abstracted by evaporation. They remain, therefore, mixed with the general mass of waters, which are, in general, more salt in proportion to their distance from the mouths of rivers, and where the heat of the climate produces the greatest evaporation. That the second cause acts more powerfully than perhaps the first, is proved by this circumstance, that all lakes from which rivers issue are not salt, but almost all those which receive rivers and discharge none, are impregnated with salt. The Caspian Sea, Lake Aral, the Dead Sea, &c. owe their saltiness solely to the salts transported thither by the rivers, and which cannot be carried off by evaporation.

III.

Of perpendicular Cataracts.

IN p. 279. I remarked, that the cataract of Niagara in Canada was the most famous, and that it fell from a perpendicular height of 156 feet. I have since been informed *, that there is a cataract in Europe, which falls from a height

* Note communicated to M. de Buffon by M. Frefnoye.

height of 300 feet. It is that of *Terni*, a small village on the road from Rome to Bologna. It is formed by the river *Velino*, which derives its source from the mountains of *Abbruzzo*. After passing by *Riette*, a village on the frontier of the kingdom of *Naples*, it falls into the *Lac de Luco*, which seems to be supplied by abundant sources ; for the river runs out of it with more force than it enters, and proceeds to the foot of the mountain *del Marmore*, from which it is precipitated by a fall of 300 feet. It is received by a kind of abyfs, from which it escapes with great tumultuousness. The celerity of its fall breaks the water with such force against the rocks and the bottom of the abyfs, that a humid vapour arises, in which many rainbows of various sizes are formed by the rays of the sun ; and, when the south wind blows, and drives this mist against the mountain, instead of several small rainbows, the whole cascade is crowned with a very large one.

ADDI-

*ADDITIONS and Corrections to the article,
Of Seas and Lakes, Vol. I. p. 290.*

Of the Limits of the South Sea.

THE South Sea is much broader than the Atlantic, and appears to be bounded by two chains of mountains, which correspond as far as the Equator. The first chain is composed of the mountains of California, of New Mexico, of the Isthmus of Panama, of the Cordeliers, of Peru, of Chili, &c. The other chain stretches through Kamtschatka, Yesso, and Japan, and extends as far as the Larron islands, and even the New Philippines. The direction of these chains of mountains, which appear to be the ancient limits of the Pacific Ocean, is precisely from north to south; so that the Old Continent was bounded on the east, by one of these chains of mountains, and the New Continent by the other. Their separation happened at the period when the waters, proceeding from the south pole, began to run between these two chains of

of

of mountains, which seem to unite, or at least to make a very near approach to each other towards the northern regions. This is not the only indication of the ancient union of the two continents on the north. This continuity of the two continents between Kamtschatka and the most western lands of America, seems now to be proved by the new discoveries of navigators, who have found, under the same parallel of latitude, a great number of islands lying so near each other, as to leave only small intervals of sea between the east of Asia and the west of America under the Polar Circle.

II.

Of double Currents in some parts of the Ocean,
Vol. I. p. 313.

I HAD too generally and too positively asserted, that, in no part of the sea, a superior and inferior current are to be found.

I have since received information, which seems to prove, that this effect actually exists, and can even be demonstrated, in certain parts of the sea. On this subject, M. Deslandes, an able navigator, obligingly communicated to me the following accurate remarks, in two letters, the
one

one dated December 6. 1770, and the other November 5. 1773.

' In your *Theory of the Earth*, Art. XI. Of
' *Seas and Lakes*, you say, that a double current
' has been alledged to run through the straits of
' Gibraltar; but that those who support this opi-
' nion have been deceived by the regorging of the
' water near the shores, which often produces a
' motion opposite to that of the principal current,

' After reading this passage, I determined to
' transmit you my observations on the subject.

' Two months after my departure from
' France, I reconnoitered the land between
' Capes Gonsalvas and Saint Catharine. The
' force of the currents, the direction of which is
' to the north north-west, corresponding exactly
' with the situation of the lands, obliged me to
' cast anchor. The general winds of this region
' blow from the south south-east, south south-
' west, and south-west. I spent two months
' and a half in making fruitless attempts to
' change my situation, and to reach the coast of
' Loango, where I had some business to transact.
' During this time, I remarked, that the sea de-
' scended in the above direction from half a
' league to a league in the hour, and that, at
' certain depths, the currents ascended below
' with the same rapidity as they descended a-
' bove.

' I ascertained the depth of these opposite cur-
 ' rents in the following manner. Being moor-
 ' ed in eight fathoms water, and the sea ex-
 ' tremely clear, I fixed a lead of thirty pounds
 ' weight to the end of a line. At about two fa-
 ' thoms from the lead, I tied a table napkin to
 ' the line by one of its corners, and allowed the
 ' lead to sink in the water. As soon as the table
 ' napkin entered, it took the direction of the
 ' first current. Continuing to observe it, I made
 ' it descend. Whenever I perceived that the
 ' current discontinued, I stopped. It then float-
 ' ed indifferently around the line. In this place,
 ' therefore, the run was interrupted. I then
 ' sunk the table napkin about a foot lower,
 ' and it assumed an opposite direction. By
 ' marking the line at the surface of the water,
 ' I found that the table napkin was at the depth
 ' of three fathoms; from which I concluded, af-
 ' ter different examinations, that, of eight fa-
 ' thoms water, three ran north north-west, and
 ' five ran in the contrary direction of south
 ' south-east.

' The same day, I repeated the experiment
 ' in fifty fathoms water, being then distant from
 ' the land six or seven leagues. I was surprised
 ' to find that the upper current was deeper in
 ' proportion to the depth of the bottom. Of
 ' fifty fathoms water, I reckoned that from
 ' twelve to fifteen ran in the first direction. This

' phaenomenon did not take place during the
 ' whole two months and a half that I remained
 ' on this coast, but nearly one month only, and
 ' at different times; during these interruptions
 ' the whole water ran into the gulf of Guiney.

' This opposition of currents suggested the
 ' idea of a machine, which, being sunk as
 ' far as the inferior current, and presenting a
 ' great surface, might force my vessel against
 ' the superior current, I made the experiment
 ' in miniature upon a boat; and I proceed-
 ' ed so far as to produce an equilibrium be-
 ' tween the force of the superior current, join-
 ' ed to that of the wind, upon the boat, and
 ' the force of the inferior current upon the ma-
 ' chine. I had not an opportunity of making
 ' trials on a larger scale. What I have related,
 ' Sir, is a truth which may be confirmed by e-
 ' very navigator who has visited these climates.

' I imagine that the winds, as well as the ri-
 ' vers, which discharge themselves into the sea
 ' along this coast, and carry great quantities of
 ' earth into the gulf of Guiney, are the princi-
 ' pal causes of these effects. Besides, the bottom
 ' of this gulf, which, by its declivity, obliges the
 ' tide to run retrograde whenever it arrives at a
 ' certain level, and is incessantly pressed by fresh
 ' quantities, while the wind acts in a contrary
 ' direction upon the surface, and constrains part
 ' of the water to observe its ordinary course.
 ' This seems to be the more probable, because
 ' the

‘ the sea enters from all quarters into this gulf,
 ‘ and issues only by revolutions which seldom
 ‘ happen. The moon has no apparent effect ;
 ‘ for the same thing takes place during all its
 ‘ phases.

‘ I had occasion to be still farther convinced
 ‘ that the pressure of the water, when it comes
 ‘ to its level, joined to the inclination of the bot-
 ‘ tom, are the sole causes of this phaenomenon.
 ‘ I found, that these currents exist only in pro-
 ‘ portion to the smaller or greater declivity of
 ‘ the shores ; and I have every reason to believe,
 ‘ that they are not perceived beyond twelve or
 ‘ fifteen leagues from land, which is the great-
 ‘ est distance along the coast of Angola, where
 ‘ we can be certain of finding the bottom. . . .

‘ The following circumstances seem to prove,
 ‘ that similar changes in the currents take place
 ‘ in the open sea. I made one of my experi-
 ‘ ments at a mean depth, namely thirty-five fa-
 ‘ thoms. I found, at the depth of six or seven
 ‘ fathoms, that the course of the water ran
 ‘ north north-west. On sinking two or three
 ‘ fathoms more, my line stretched to the west
 ‘ north-west. At three or four fathoms deeper,
 ‘ the course was west south-west, then south-
 ‘ west, and south. Lastly, at twenty-five and
 ‘ twenty-six fathoms, the course was south
 ‘ south-east, and towards the bottom it was
 ‘ south-east and east south-east. From these
 ‘ experiments I drew the following conclusions :

' That I might compare the ocean between A-
 ' frica and America to a great river, the course
 ' of which is almost constantly directed to the
 ' north-west ; that, as it runs along, it carries
 ' down sand and mud, which it deposits on its
 ' banks. These banks are, of course, heighten-
 ' ed, and necessarily raise the level of the water,
 ' and oblige it to run retrograde in proportion
 ' to the declivity of the shore. But, as the wa-
 ' ter is directed by a primitive impulse, it can-
 ' not return in a straight line : Obeying the o-
 ' riginal movement, and yielding reluctantly to
 ' the last obstacle, it must necessarily describe a
 ' curve of greater or smaller extent, till it meets
 ' the middle current with which it may partly
 ' unite, or which may serve it as a fulcrum, and
 ' give it a direction contrary to that impressed
 ' on it by the bottom. As the mass of water is
 ' in perpetual motion, the water towards the
 ' bottom, being nearer the cause and more pres-
 ' sed, must always undergo the first changes,
 ' and run in a direction contrary to the superior
 ' current, while the same cause reaches not dif-
 ' ferent heights. These, Sir, are my ideas.
 ' I have frequently taken advantage of these in-
 ' ferior currents ; by sinking a machine to dif-
 ' ferent depths, according to the number of fa-
 ' thoms water I happened to be in, I was en-
 ' abled to sail against the upper current. I
 ' found, that, in calm water, and with a surface
 ' three

‘ three times larger than that part of the prow
 ‘ which is below the water, we could run from
 ‘ a third to half a league in the hour. Of this
 ‘ fact I was ascertained by my latitude, by boats
 ‘ which I anchored, and from which I found
 ‘ myself at a great distance an hour afterward ;
 ‘ and, lastly, by the distance of certain points a-
 ‘ long the coasts.’

These observations of M. Deslandes seem to be decisive, and I accede to them with pleasure. I cannot sufficiently thank him for demonstrating not only that my ideas on this subject were, in general, just, but that, in particular circumstances, they were liable to exceptions. It is not less certain, however, that the ocean forced open the strait of Gibraltar, and, consequently, that the Mediterranean sea received a great augmentation by this irruption. I rested this opinion not only on the current of the ocean into the Mediterranean, but on the situation of the land and the correspondence of the strata on the opposite coasts, which has often been remarked by intelligent navigators. ‘ The irruption which
 ‘ formed the Mediterranean is evident, as well
 ‘ as that of the Black Sea by the strait of the
 ‘ Dardanelles, where the current is always violent, and the correspondence of the angles of
 ‘ the two coasts strongly marked, as well as the
 ‘ similarity of the strata, which are precisely the
 ‘ same on the opposite sides *.’

F 3

Besides,

* Part of a letter written to M. de Buffon in 1772.

Besides, the idea of M. Deslandes, who considers the sea between Africa and America as a great river, the course of which is toward the north-west, agrees perfectly with what I advanced concerning the water's running in greater quantity from the south than from the north pole.

III.

Of the Northern Parts of the Atlantic Ocean,

ON viewing the islands and gulfs, which are very numerous round Greenland, it is difficult, as navigators remark, not to suspect that the sea falls back from the Poles towards the Equator. What favours this conjecture, the tide rises eighteen feet at Cape des Etats, and only eight feet in the bay of Disko, *i. e.* at ten degrees of higher latitude*.

This observation, joined to that of the preceding article, seems still farther to confirm the movement of the waters of the ocean from the southern to the northern regions, where they are forced, by the resistance of the lands, to re-gorge or flow back toward the south.

In Hudson's bay, vessels have to preserve themselves from mountains of ice, which are said

* Hist. gen. des voyages, tom. 19. p. 2.

said to be from fifteen to eighteen hundred feet thick, and which, being formed by a succession of long winters, in small gulfs perpetually filled with snow, have been detached by the north-west winds, or by some other powerful cause.

The north-west wind, which prevails perpetually during winter, and often in summer, excites, in the same bay, dreadful tempests. These are still more to be apprehended, because shoals are here very frequent. In the countries which bound this bay, the sun never rises nor sets without a great cone of light. When this phaenomenon disappears, it is succeeded by the *aurora borealis*. Here the heavens are seldom serene. In spring and autumn the air is generally replete with thick fogs; and, during winter, with an infinity of small threads of ice, which are visible to the eye. Though the summer heats are considerable during two months or six weeks, thunder and lightning are rare*.

The sea along the coasts of Norway, which are bordered with rocks, is commonly from a hundred to four hundred fathoms deep, and the water is less salt than in warmer climates. The number of oily fishes with which this sea is filled, renders it so fat that it is almost inflammable.

* Hist. Philos. et politique, tom. 6. p. 308. 309.

ble. The tide is here inconsiderable, the highest not rising above eight feet *.

Some observations have lately been made upon the temperature of the land and water in the climates adjacent to the north Pole.

' In Greenland, the cold begins with the new year, and becomes so piercing in the months of February and March, that the stones split, and the sea smokes like a furnace, especially in the bays. In the midst of this thick fog, however, the frost is not so intense, as when the sky is unclouded; for, when we pass from the land to that foggy atmosphere which covers the surface and margins of the waters, we feel a milder air, though our hair and clothes are stiffened with hoar-frost. This fog produces more chilblains than a dry cold; and, when it passes from the sea to a colder atmosphere, it instantly freezes, is dispersed through the horizon by the wind, and produces a cold so intense that no person can go into the open air, without running the hazard of having his hands and feet entirely frozen. It is in this season, that we see the water freeze on the fire before it boils. It is then that the winter paves a road of ice between islands, and in the bays and straits.

' Autumn is the finest season in Greenland,

' But

* Pontoppidan's Nat. hist. of Norway; *journal étranger*, Août 1755.

‘ But its duration is short, and frequently interrupted by cold frosty nights. It is also about this time, that, in an atmosphere darkened with vapours, we see fogs which freeze and form a tiffue on the sea similar to cobwebs; and, in the fields, the air is impregnated with lucid atoms, or sharp icicles like small needles.

‘ It has often been remarked, that the seasons in Greenland assume a temperature opposite to that which prevails in the rest of Europe. When the winter is rigorous in the temperate climates, it is mild in Greenland; and very severe in this northern region, when it is moderate in our countries. At the end of the year 1739, the winter was so mild in the bay of Disko, that the geese, in the month of January, passed from the temperate to the frozen zone in quest of warmer air; and that, in 1740, no ice was seen at Disko in the month of March; while, in Europe, the ice prevailed, without interruption, from October to May.

‘ In winter 1763, which was extremely cold over all Europe, the cold was so little felt in Greenland, that some summers have been less mild*.

We are assured by voyagers, that, in the seas adjacent to Greenland, there are very high mountains of floating ice, and others which resemble
rafts

* Hist. gen. des voyages, tom. 19. p. 20. &c.

rafts of two hundred fathoms in length, by sixty or eighty in breadth. But these boards of ice, which form immense plains upon the sea, are seldom above nine or twelve feet thick. They seem to be formed immediately on the surface when the cold is greatest. But the floating and very high masses come from the land, i. e. from the environs of mountains and coasts, from which they have been detached and carried down to the sea by the rivers. These masses of ice bring along with them great quantities of wood, which are afterwards thrown by the sea upon the eastern coasts of Greenland. This wood, it appears, neither comes from Labrador nor Norway; because the north-east winds, which are very violent in these countries, would push back the trees, and the currents which run to the south of Davis's strait, and Hudson's bay, would stop all that might come from America to the coasts of Greenland.

The sea begins to carry boards of ice to Spitzbergen in the months of April and May. A great number come from Davis's strait, part of them from Nova Zembla, and the greatest number from the east coast of Greenland, being transported from east to west according to the general movement of the ocean.

The following facts and notices are to be found in the voyage of Captain Phipps. 'The idea of a passage to the East Indies by the
'North

' North Pole was suggested as early as the year
 ' 1527, by Robert Thorne, merchant of Bris-
 ' tol. No voyage, however, appears to
 have been undertaken to explore the circumpo-
 lar seas, till the year 1607, when ' Henry Hud-
 ' son was set forth, at the charge of certain wor-
 ' shipful merchants of London, to discover a pas-
 ' sage by the North Pole to Japan and China.
 ' And this I can assure at this present, that
 ' between seventy-eight degrees and a half, and
 ' eighty-two degrees, by this way there is no
 ' passage.

' In 1609, a voyage was set forth by the
 ' Right Worshipful Sir Thomas Smith to the
 ' south part of Spitzbergen; and, when near
 ' Foreland, he sent his mate ashore; and speak-
 ' ing of the account he gave at his return, says,
 ' Moreover, I was certified that all the ponds
 ' and lakes were unfrozen, they being fresh wa-
 ' ter; which putteth me in hope of a mild sum-
 ' mer here, after so sharp a beginning as I have
 ' had; and my opinion is such, and I assure
 ' myself it is so, that a passage may be as soon
 ' attained this way by the Pole, as any unknown
 ' way whatsoever, by reason the sun doth give
 ' a great heat in this climate, and the ice (I
 ' mean that freezeth here) is nothing so huge as
 ' I have seen in seventy-three degrees. . . . Se-
 ' veral other voyagers have attempted to disco-
 ' ver this passage, but without success.

On

On the fifth of July, Captain Phipps saw great quantities of floating ice about the $79^{\circ} 34'$ of latitude. The weather was foggy. The next day he continued his course as far as the $79^{\circ} 59' 39''$ between Spitzbergen and the ice. On the 7th, he proceeded through the floating masses of ice in quest of an open passage to the north by which he might gain an open sea. But the ice to the north-north-west formed one continued mass; and at $80^{\circ} 36'$ the sea was entirely frozen; so that all the attempts of Captain Phipps to discover a passage proved abortive.' 'On the 12th of September, Dr Irvine tried the temperature of the sea in a state of great agitation, and found it considerably warmer than that of the atmosphere. This observation is the more interesting, as it agrees with a passage in Plutarch's Natural Questions, not (I believe) before taken notice of, or confirmed by experiment; in which he remarks, 'that the sea becomes warmer by being agitated in waves. . . . These gales are as common in the spring as in the autumn; there is every reason to suppose, therefore, that at an early season we should have met with the same bad weather in going out as we did on our return.' And, as Captain Phipps departed from England in the end of May, he certainly took the season most favourable to his expedition. . . . 'There was also most probability, if ever navigation should be practicable to the Pole,

‘ Pole, of finding the sea open to the northward
 ‘ after the solstice; the sun having then exerted
 ‘ the full influence of his rays, though there was
 ‘ enough of the summer still remaining for the
 ‘ purpose of exploring the seas to the northward
 ‘ and westward of Spitzbergen.’

I agree entirely with this able navigator; and I suspect that the expedition to the Pole cannot be renewed with success, and that we can never reach beyond the 82d or 83d degree. We are assured that a vessel from Whitby, in the year 1774, penetrated as far as the 80th degree, without seeing ice sufficient to prevent sailing still farther. A Captain Robinson is likewise quoted, from whose journal it appears that, in 1773, he arrived at the 81° 30'. Lastly, a Dutch ship of war, sent to protect the whale-fishers, is said to have advanced, about fifty years ago, as far as the 88th degree. Dr Campbell, it is added, received this intelligence from a Dr *Daille*, who was in the vessel, and practised physic in London in the year 1745 *. This is probably the same navigator whom I formerly quoted under the name of Captain Mouton. But I am extremely suspicious of the fact; and I am persuaded, that we shall in vain attempt to reach beyond the 82d or 83d degree, and that, if a passage by the north is practicable, it can only be by the way of Hudson's bay.

On

* Gazette de Literature, Août 9. 1774, No. 61.

On this subject, the following passage of the learned and ingenious author of the history of the Two Indies merits attention, 'Hudson's bay always has been, and is still looked upon as the nearest road from Europe to the East Indies, and to the richest parts of Asia.

'Cabot was the first who entertained an idea of a north-west passage to the South-seas; but his discoveries ended at Newfoundland. After him followed a crowd of English navigators, many of whom had the honour of giving their names to savage coasts which no mortal had ever visited before. These bold and memorable expeditions were more striking than really useful. The most fortunate of them did not furnish a single idea relative to the object of pursuit. The Dutch, less frequent in their attempts, and who pursued them with less ardour, were of course not more successful, and the whole began to be treated as a chimera, when the discovery of Hudson's bay rekindled all the hopes that were nearly extinguished.

'From this time the attempts were renewed with fresh ardour. Those that had been made before in vain by the mother-country, whose attention was engrossed by her own intestine commotions, were pursued by New England, whose situation was favourable to the enterprise. Still, however, for some time there were more voyages undertaken than discoveries

'ries made. The nation was a long time kept
 'in suspense by the contradictory accounts recei-
 'ved from the adventurers. While some main-
 'tained the possibility, some the probability,
 'and others asserted the certainty of the passage;
 'the accounts they gave, instead of clearing up
 'the point, involved it in still greater darkness.
 'Indeed, these accounts are so full of obscurity
 'and confusion, they are silent upon so many
 'important circumstances, and they display such
 'visible marks of ignorance and want of vera-
 'city, that, however impatient we may be of de-
 'termining the question, it is impossible to build
 'any thing like a solid judgment upon testimo-
 'nies so suspicious. At length, the famous
 'expedition of 1746 threw some kind of light
 'upon a point which had remained enveloped in
 'darkness for two centuries past. But upon
 'what grounds have the later navigators enter-
 'tained better hopes? What are the experiments
 'on which they found their conjectures?

'Let us proceed to give an account of their
 'arguments. There are three facts in natural
 'history, which henceforward must be taken
 'for granted. The first is, that the tides come
 'from the ocean, and that they extend more
 'or less into the other-seas, in proportion as
 'their channels communicate with the great
 'reservoir by larger or smaller openings; from
 'whence it follows that this periodical motion

' is scarcely perceptible in the Mediterranean, in
' the Baltic, and other gulfs of the same nature.
' A second matter of fact is, that the tides are
' much later and much weaker in places more
' remote from the ocean, than in those which
' are nearer to it. The third fact is, that vio-
' lent winds, which blow in a direction with the
' tides, make them rise above their ordinary
' boundaries, and that those which blow in a
' contrary direction retard their motion, at the
' same time that they diminish their swell.
' From these principles, it is most certain that,
' if Hudson's bay were no more than a gulf in-
' closed between two continents, and had no
' communication but with the Atlantic, the tides
' in it would be very inconsiderable; they would
' be weaker in proportion as they were further
' removed from the source, and would be less
' strong wherever they ran in a contrary direc-
' tion to the wind. But it is proved by obser-
' vations made with the greatest skill and preci-
' sion, that the tides are very high throughout
' the whole bay. It is certain that they are
' higher towards the bottom of the bay than e-
' ven in the strait itself, or at least in the neigh-
' bourhood of it. It is proved that even this
' height increases whenever the wind blows from
' a corner opposite to the strait; it is, there-
' fore, certain, that Hudson's bay has a com-
' munication

‘munication with the ocean; beside that which
 ‘has been already found out.

‘Those who have endeavoured to explain
 ‘these very striking facts, by supposing a com-
 ‘munication of Hudson’s with Baffin’s bay, or
 ‘with Davis’s straits, are evidently mistaken.
 ‘They would not scruple to reject this opinion,
 ‘for which indeed there is no real foundation,
 ‘if they only considered that the tides are much
 ‘lower in Davis’s straits, and in Baffin’s bay,
 ‘than in Hudson’s.

‘But if the tides in Hudson’s bay can come
 ‘neither from the Atlantic ocean, nor from a-
 ‘ny other northern sea, in which they are con-
 ‘stantly much weaker, it follows that they must
 ‘have their origin in the South Sea. And this
 ‘is still further apparent from another leading
 ‘fact, which is, that the highest tides ever
 ‘observed upon these coasts, are always occa-
 ‘sioned by the north-west winds, which blow
 ‘directly against the mouth of the strait.

‘Having thus determined, as much as the na-
 ‘ture of the subject will permit, the existence
 ‘of this passage so long and so vainly wished-for,
 ‘the next point is to find out in what part of
 ‘the bay it is to be expected. From consider-
 ‘ing every circumstance, we are induced to
 ‘think that the attempts, which have been hi-
 ‘therto made without either choice or method,
 ought to be directed towards Welcome bay, on

‘ the western coast. First, the bottom of the sea
‘ is to be seen there at the depth of about eleven
‘ fathom, which is an evident sign that the wa-
‘ ter comes from some ocean, as such a transpa-
‘ rency could not exist in waters discharged from
‘ rivers, or in melted snow or rain. Secondly,
‘ the currents keep this place always free from
‘ ice, while all the rest of the bay is covered
‘ with it; and their violence cannot be account-
‘ ed for but by supposing them to come from
‘ some western sea. Lastly, the whales, who
‘ towards the latter end of autumn always go in
‘ search of the warmest climates, are found in
‘ great abundance in these parts towards the end
‘ of summer, which would seem to indicate that
‘ there is an outlet for them from thence to the
‘ south seas, not to the northern ocean.

‘ It is probable that the passage is very short.
‘ All the rivers that empty themselves on the
‘ western coast of Hudson’s bay are small and
‘ slow, which seems to prove that they do not
‘ come from any distance; and that consequent-
‘ ly the lands which separate the two seas are of
‘ a small extent. This argument is strengthened
‘ by the height and regularity of the tides.
‘ Wherever there is no other difference between
‘ the times of the ebb and flow, but that which
‘ is occasioned by the retarded progression of
‘ the moon in her return to the meridian, it is
‘ a certain sign that the ocean from whence
‘ those

those tides come is very near. If the passage is short, and not very far to the north, as every thing seems to promise, we may also presume that it is not very difficult. The rapidity of the currents observable in these latitudes, which prevents any flakes of ice from continuing there, cannot but give some weight to this conjecture.

I believe, with this excellent writer, that if a practicable passage exists, it must be at the bottom of Hudson's bay, and that all attempts by Baffin's bay will be fruitless, because the climate is too cold, and its coasts are always frozen, especially towards the north. But the existence of this passage is rendered still more doubtful by the lands discovered, in 1741, by Bering and Tchirikow, under the same latitude with Hudson's bay; for these lands seem to form a part of the great Continent of America, which appears to stretch under the same latitude as far as the Polar circle. Of course, the passage into the south sea can only be found about the 55th degree of north latitude.

IV.

Of the Caspian Sea, Vol. I. p. 327.

TO what was advanced in order to prove,
G 2 that

that the Caspian sea is only a lake, and never had any communication with the ocean, I have to add the answers I received from the Academy of Petersburg to some queries I transmitted them concerning this sea.

‘ Augusto 1748, October 5. &c. Cancellaria
 ‘ Academiæ Scientiarum mandavit, ut Astra-
 ‘ chanensis Gubernii Cancellaria responderet
 ‘ ad sequentia. 1. Suntne vortices in mari
 ‘ Caspico necne! 2. Quæ genera piscium
 ‘ illud inhabitant! Quomodo appellantur!
 ‘ Et an marini tantum aut et fluviatiles ibidem
 ‘ reperiantur! 3. Qualia genera concharum!
 ‘ Quæ species ostrearum et cancrorum occur-
 ‘ runt! 4. Quæ genera marinarum avium
 ‘ in ipso mari aut circa illud versantur! ad
 ‘ quæ Astrachensis Cancellaria d. 13. Mart.
 ‘ 1749, sequentibus respondit.

‘ Ad 1. in mari Caspico vortices occurrunt
 ‘ nusquam; hinc est quod nec in mappis marinis
 ‘ extant, nec ab ullo officialium rei navalis visi
 ‘ esse perhibentur.

‘ Ad 2. pisces Caspium mare inhabitant; A-
 ‘ cipenser, Sturioli, Gmel, Siruli Cyprini
 ‘ clavati, Brame, Percae, Cyprini ventre acuto,
 ‘ ignoti alibi pisces, tincae, salmones, qui,
 ‘ ut e mari fluvios intrare, ita et in mare e fluviis
 ‘ remeare solent;

‘ Ad 3. conchae in littoribus maris obviae
 ‘ quidem sunt, sed parvae, candidae, aut ex u-

‘ nâ

‘nâ parte rubrae. Cancrî ad littora observantur
 ‘magnitudine fluviatilibus similes; ostreae autem
 ‘et capita Medusae visa sunt nusquam;

‘Ad 4. aves marinae quae circa mare Cas-
 ‘pium versantur sunt anseres vulgâres et rubri,
 ‘pelicani, cygni, anates rubrae et nigricantes,
 ‘aquilae, corvi aquatici, grûes, plateae, ardeae
 ‘albae, cinereae, et nigricantes, ciconiae albae
 ‘gruibus similes, Karawaiki (igotum avis no-
 ‘men) larorum variae species, sturni nigri et
 ‘lateribus albis instar picarum, physiani, anseres
 ‘parvi nigricantes, Tudaki (ignotum avis no-
 ‘men) albo colore praediti.’

These facts, which are both accurate and authentic, confirm my position, that the Caspian sea has no subterraneous communication with the ocean. They prove farther, that this sea never formed a part of the ocean; for it contains neither oysters nor any other sea-shells, but such species only as are found in rivers. We are, therefore, warranted to conclude, that this sea is nothing but a great lake formed by the waters of rivers, since we find in it the same fishes and the same shells which inhabit the rivers, and none of those which people the ocean, or the Mediterranean.

V.

Of the Salt Lakes of Asia.

IN the country of the Ufian Tartars, so called because they inhabit the banks of the river Uf, there are, M. Pallas remarks, lakes, the waters of which were formerly fresh, and are now salt. He makes the same remark concerning a lake near Miacs.

One of the lakes most famous for the quantity of salt extracted from it, is that near the banks of the river Isel, called *Soratschya*. The salt of it, in general, is bitter, and employed by the physicians as a good purgative. Two ounces of this salt makes a very strong dose. Near Kurtenegsch, the shoals are covered with a bitter salt, which rises, like a field of snow, to the height of two inches. The lake Korjackof furnishes annually three hundred thousand cubic feet of salt *. Lake Jennu likewise furnishes a great quantity.

In the voyages performed under the auspices of the Academy of Petersburg, mention is made of the salt lake of Jamuscha in Siberia. This lake, which is nearly round, is only about nine leagues in circumference. Its margins are covered

* The cubic foot weighs thirty-five pounds each of sixteen ounces.

vered with salt, and the bottom is clothed with crystals of salt. The water is extremely salt; and, when the sun shines, it appears reddish like the sky in a fine morning. The salt is as white as snow, and forms itself into cubic crystals. The quantity of it is so immense, that a number of vessels may, in a short time, be loaded with it; and, after it has been removed, it is again replaced in five or six days. It is sufficient to remark, that it supplies the provinces of Tobolski and Jeniseik, and that this lake could supply fifty provinces of similar extent. The commerce of this, as well as of all other salt, is reserved in the hands of the crown. This salt is exceedingly good. It surpasses all others in whiteness, and none is more proper for curing meat. In the south of Asia, there are likewise salt lakes, one near the Euphrates, and another in the neighbourhood of Barra. There are others, it is said, near Haleb, and at Larneca in the island of Cyprus. This last borders upon the sea. The salt valley of Barra, being at no great distance from the Euphrates, might be worked, if its waters were made to run into this river, and if the earth was good: But at present this earth yields a good salt for the kitchen, and even in such quantity that the Bengal vessels, when returning in ballast, take in loadings of this salt *.

ADD L.

* Descript. de l'Arabie, par M. Niebuhr, p. 2.

*ADDITIONS and Corrections to the Article,
Of Inequalities at the bottom of the Sea,
and of Currents, Vol. I. p. 351.*

I.

Of the Nature and Quality of the soil at the bottom of the Sea, p. 357.

M. l'Abbé Dicquemare, a learned natural philosopher, has made some observations on this subject, which seem to accord with what I have advanced in my Theory of the Earth.

Conversations with pilates of all languages, the perusal of charts and soundings both ancient and modern, the examination of such bodies as attach themselves to the plummet, the inspection of coasts, banks, and of the strata which compose the interior parts of the earth, to a depth nearly equal to the length of our common plumb lines, some reflections which are most analogous to this subject arising from physics, cosmography, and natural history, have made me suspect, nay, have even convinced me, says M. l' Abbé Dicquemare, 'that, in some
places,

' places, there must be two different bottoms,
 ' the one often covering the other at intervals :
 ' The ancient and permanent, which may be
 ' called the general bottom, and the other acci-
 ' dental or particular. The first, which ought to
 ' form the basis of a general picture, is the soil
 ' of the basin that contains the sea. It is com-
 ' posed of the same strata which we every
 ' where find in the bowels of the earth, such as
 ' marl, stone, clay, sand, shells, all disposed ho-
 ' rizontally, and of an equal thickness through
 ' a great extent. . . Here, we find a bottom
 ' of marl, there a bottom of clay, sand, or rock.
 ' Lastly, the number of general bottoms disco-
 ' verable by sounding exceeds not six or seven
 ' species. The most extensive and thickest of
 ' these strata, being uncovered, or cut perpendi-
 ' cularly, form great spaces in the sea, where
 ' we ought to recognise the general bottom, in-
 ' dependent of such foreign substances as
 ' may be deposited by currents or other causes.
 ' There are other permanent bottoms which
 ' we have not hitherto mentioned : These are
 ' those immense masses of madrepores and
 ' corals, which often cover a bottom of rock,
 ' and those enormous and extended banks of
 ' shells, which a rapid multiplication, or other
 ' causes, have accumulated, and which occur in
 ' different places, as it were in colonies. One
 ' species occupies a certain extent; the succeed-
 ' ing

ing space is occupied by another species, in the same manner as has been remarked with regard to fossil shells, in a great part of Europe, and perhaps every where else. It is by observations on the interior parts of earth, and on such places as the sea leaves uncovered, where we always see particular species reigning over certain districts, that we have been enabled to form some idea of the prodigious number of individuals, and of the thickness of the banks at the bottom of the sea, of which we can only know the surface by our soundings.

The accidental or particular bottom is composed of immense numbers of the prickles of the sea-archin ; of fragments of shells, sometimes corrupted ; of crustaceous animals ; of madrepores ; of sea plants ; of pyrites ; of granites rounded by friction ; of pieces of mother-of-pearl ; of mica ; perhaps of talc, to which different names are given according to their appearances ; of entire shells, but in small quantity, and seemingly dispersed through no great extent ; of small flints, some crystals, coloured sands, a light slime, &c. All these bodies, disseminated by the currents, the agitation of the waters, and partly proceeding from the rivers, from the sinking of hills or high beaches, and other accidental causes, seldom perfectly cover the general bottom, which ap-

'pears every instant, when we found often in the
'same regions. . . . I remarked, that, during
'near a century, a great part of the general
'bottoms of the gulf of Gascony and la Man-
'cha, have suffered little or no change, which
'supports my opinion concerning the two
'bottoms *.'

II.

Of Currents in the Ocean, Vol. I. p. 365.

TO the enumeration of currents, we shall add
the famous current of Mosckoe, Mosche, or Male,
on the coast of Norway, of which a learned
Swede has given the following description.

'This current, which took its name from the
'rock of Moschenficle, situated between the two
'islands of Tofode and Woeroen, extends four
'miles from north to south.

'It is extremely rapid, especially between the
'rock of Mosche and the point of Lofode. But,
'in proportion as it approaches the two isles of
'Woeroen and Roest, its rapidity diminishes.
'It finishes its course from north to south in six
'hours, and from south to north in an equal
'time.

This
* Journ. de phys. par M. Abbé Rozier, Dec. 1775, p. 438.

' This current is so rapid, that it produces a
' number of small eddies, which the Norwegians
' call *gargamer*.

' Instead of following the course of the tides,
' it observes an opposite direction. When the
' waters of the ocean rise, they proceed from
' south to north, but the current then runs from
' north to south. When the sea retires, it goes
' from north to south, but the current then runs
' from south to north.

' It is remarkable, that, both in going and re-
' turning, it does not describe a straight line, like
' other currents found in some straits, where the
' waters of the sea rise and fall; but it moves in
' a circular direction.

' When the waters of the sea have risen one
' half, those of the current run to the south south-
' east. In proportion as the sea rises, the current
' turns towards the south; from thence it turns
' toward the south-west, and from the south-west
' to the west.

' When the tide is full, the current goes to-
' ward the north-west, and then toward the
' north. About the middle of the reflux, the
' current recommences its course, after having
' been suspended during some seconds.

' The principal phaenomenon is its return by
' the west from the south south-east toward the
' north. If it did not come back by the same
' road, it would be difficult and almost impossible

' to sail from the point of Lofoede to the two
 ' great islands of Woeroen and Rouest. There
 ' are two parishes, which would necessarily be un-
 ' inhabited, if the current observed not the course
 ' I have described. But, as it actually observes
 ' this course, those who pass from the point of
 ' Lofoede to the two islands, wait till the tide
 ' has risen one half, because the direction of the
 ' current is then to the west. When they want
 ' to return from these islands to the point of
 ' Lofoede, they wait till the tide be half ebb ;
 ' because the course of the current is then toward
 ' the Continent. This circumstance renders the
 ' passage very easy. . . Now, there is no current
 ' without a declivity ; and here the water rises
 ' on one side and descends by the other.

' To be convinced of this truth, we have only
 ' to consider that there is a small tongue of land
 ' in Norway which extends sixteen miles into
 ' the sea, from the point of Lofoede, which in-
 ' clines more to the west, as far as that of Lod-
 ' dinge, which inclines more to the east. This
 ' tongue of land is surrounded by the sea ; and,
 ' whether during the flux or reflux, the water
 ' is always stopt there ; because it can have no
 ' issue but through six small straits or passages
 ' which divide the tongue of land into an equal
 ' number of portions. Some of these exceed not
 ' half a quarter of a mile in breadth, and some-
 ' times not half so much. Hence they can con-
 ' tain

tain only a small quantity of water. Of course, when the sea rises, a great part of the water coming to the north is stopt to the south of this tongue of land. The waters are, therefore, much more elevated toward the south than toward the north. When the sea retires, and goes toward the south, a great part of the water, in the same manner, is arrested to the north of this tongue of land, and, consequently, is much higher towards the north than towards the south.

The waters thus interrupted sometimes, at the north and sometimes at the south, can find an issue only between the point of Lofoeede and the island of Woeroen, and between this island and that of Rouest.

The declivity of the waters, when they descend, produces the rapidity of the current; and, for the same reason, this rapidity is greatest toward the point of Lofoeede. As this point is nearest the place where the waters are stopt, the rapidity there is likewise greatest; and, in proportion as the waters of the current extend toward the islands of Woeroen and Rouest, their celerity decreases.

It is now easy to conceive why the current is always diametrically opposite to the motion of the sea. Nothing opposes the common movements of the waters, whether they rise or fall. But the waters which are stopt above the point
of

‘ of Lofoe de can neither move in a straight
 ‘ line, nor beyond this point, while the sea has
 ‘ not descended lower, and has not, in retiring,
 ‘ carried off the waters, which those that are
 ‘ stopt above the point of Lofoe de ought to re-
 ‘ place. . . .

‘ At the commencement of the flux and reflux,
 ‘ the waters of the sea cannot turn back those of
 ‘ the current; but, when they have risen or
 ‘ fallen one half, they are then enabled to
 ‘ change the direction of the current. As it can-
 ‘ not then turn toward the east, because the water
 ‘ is always stable near the point of Lofoe de, as
 ‘ formerly remarked, it must necessarily proceed
 ‘ toward the west, where the water is lower*.’

This explication seems to be conformable to the true principles of the theory of running waters.

We must still add the description of the famous current of Scylla and Charybdis, near the island of Sicily concerning which Mr Brydone has lately made some observations tending to prove that the violence and rapidity of its movements are much diminished.

‘ It was almost a dead calm, our ship scarce
 ‘ moving half a mile in an hour, so that we had
 ‘ time to get a complete view of the famous rock
 ‘ of Scylla, on the Calabrian side, Cape Pylorus
 ‘ on the Sicilian, and the celebrated Straits of

* Descript. du courant de Mosckoe, &c. *Journal étranger*.
 Février 1758, p. 25.

‘ the Faro that runs between them. Whilſt we
‘ were ſtill ſome miles diſtant from the entry of
‘ the Straits, we heard the roaring of the current,
‘ like the noiſe of ſome large impetuous river
‘ confined between narrow banks. This in-
‘ creased in proportion as we advanced, till we
‘ ſaw the water in many places raiſed to a conſi-
‘ derable height, and forming large eddies or
‘ whirlpools. The ſea in every other place was
‘ as ſmooth as glaſs. Our old pilot told us, that
‘ he had often ſeen ſhips caught in theſe eddies,
‘ and whirled about with great rapidity, without
‘ obeying the helm in the ſmalleſt degree.
‘ When the weather is calm, there is little danger;
‘ but when the waves meet with this violent
‘ current, it makes a dreadful ſea. He ſays,
‘ there were five ſhips wrecked in this ſpot laſt
‘ winter. We obſerved that the current ſet ex-
‘ actly for the rock of Scylla, and would infal-
‘ libly have carried any thing thrown into it a-
‘ gainſt that point; ſo that it was not without
‘ reaſon the ancients have painted it as an object
‘ of ſuch terror. It is about a mile from the
‘ entry of the Faro, and forms a ſmall promon-
‘ tory, which runs a little out to ſea, and meets
‘ the whole force of the waters, as they come
‘ out of the narroweſt part of the Straits. The
‘ head of this promontory is the famous Scylla.
‘ It muſt be owned that it does not altogether
‘ come up to the formidable deſcription that
‘ Homer

' Homer gives of it ; the reading of which (like
 ' that of Shakespear's Cliff) almost makes one's
 ' head giddy. Neither is the passage so wonder-
 ' ous narrow and difficult as he makes it. In-
 ' deed it is probable that the breadth of it is great-
 ' ly increased since his time, by the violent im-
 ' petuosity of the current. And this violence, too,
 ' must have always diminished, in proportion as
 ' the breadth of the channel increased. The
 ' rock is near 200 feet high. There is a kind of
 ' castle or fort built on its summit ; and the
 ' town of Scylla, or Sciglio, containing three or
 ' four hundred inhabitants, stands on its south
 ' side, and gives the title of prince to a Calabrese
 ' family. We lay just opposite to Cape Pylorus
 ' where the light-house is now built. . . . The
 ' mouth of the Straits, betwixt the promontories
 ' of Pylorus in Sicily, and the Coda de Volpe in
 ' Calabria, appears scarcely to be a mile. But
 ' the channel enlarges to four miles in breadth
 ' near Messina, which is twelve miles from the
 ' mouth of the Straits. . . The celebrated gulf
 ' or whirlpool of Charybdis lies near to the en-
 ' try of the harbour of Messina, and often occa-
 ' sions such an intestine and irregular motion in
 ' the water, that the helm loses most of its power,
 ' and ships have great difficulty to get in, even
 ' with the fairest wind that can blow. . . . Ari-
 ' stotle gives a long and formidable description
 ' of it in his 125th chapter, De Admirandis,
 VOL. IX. H ' which

' which I find translated in an old Sicilian book
 ' I have got here. It begins, "Adeo profun-
 ' dum, horridumque spectaculum," &c. but it is
 ' too long to transcribe. It is likewise described
 ' by Homer, 12th of the *Odyſſey*; Virgil, 3d
 ' *Æneid*; Lucretius, Ovid, Salluſt, Seneca, as
 ' alſo by many of the old Italian and Sicilian
 ' poets, who all ſpeak of it in terms of horror;
 ' and repreſent it as an object that inſpired terror,
 ' even when looked on at a diſtance. It certain-
 ' ly is not now ſo formidable; and very proba-
 ' bly, the violence of this motion, continued for
 ' ſo many ages, has by degrees worn ſmooth the
 ' rugged rocks, and jutting ſhelves, that may
 ' have intercepted and confined the waters. The
 ' breadth of the Straits too, in this place, I make
 ' no doubt is conſiderably enlarged. Indeed,
 ' from the nature of things it muſt be ſo; the
 ' perpetual friction occaſioned by the current
 ' muſt wear away the bank on each ſide, and
 ' enlarge the bed of the water.

' The veſſels in this paſſage were obliged to
 ' go as near as poſſible to the coaſt of Calabria,
 ' in order to avoid the ſuction occaſioned by the
 ' whirling of the waters in this vortex; by
 ' which means, when they came to the narroweſt
 ' and moſt rapid part of the Straits, betwixt
 ' Cape Pylorus and Scylla, they were in great
 ' danger of being carried upon that rock. From
 ' whence the proverb, ſtill applied to thoſe who,
 ' in

' in attempting to avoid one evil, fall into another;

" Incidit in Scyllam, cupiens vitare Carybdim."

' Here another light-house is placed to warn
' failors of their approach to Charybdis, as that
' other on Cape Pylorus is intended to give them
' notice of Scylla *.'

H 2 ADDI-

* Brydone's Tour, vol. 1. p. 40. &c.

*ADDITIONS to the Article, Of Regular
Winds, Vol. I. p. 367.*

I.

Of Reflected Wind, p. 379.

I Shall here mention a fact which seems to have escaped the observation of natural philosophers, though every man is in a condition to convince himself of its truth. The fact is that the reflected wind is more violent than the direct, and still more so in proportion to the nearness of the obstacle by which it is reflected. I have often made the experiment by approaching a tower, of near a hundred feet high, and situated at the north of my garden at Montbard. When a strong south wind blows, we are violently pushed back, at the distance of thirty paces: After which, there is an interval for five or six paces, where the violence of the reflected wind ceases, and seems to be in equilibrium with the direct. The nearer we approach, the strength of the reflected wind augments, and

and pushes us back with much greater force, than the direct wind pushes us forward. The cause of this general effect, which may be perceived opposite to any high buildings, precipices, &c. it is not difficult to discover. The air in the direct wind acts only by its celerity and its common volume; but this volume or mass is considerably augmented by the compression it receives from the obstacle by which it is reflected; and, as the quantity of every motion consists of the celerity multiplied by the volume, this quantity is much greater after being compressed than before. It is a volume of common air which acts in the first case, and a volume of air of double or triple the density, which acts in the second.

II.

Of the state of the Air at the top of high Mountains.

IT has been proved by a thousand experiments, that the higher we rise above the level of the sea or of plains, the column of mercury in the barometer sinks the lower; and, consequently, that the weight of a column of air diminishes in proportion to the elevation of the place; and as air is an elastic and compressible fluid,

philosophers have unanimously concluded from these experiments, that the air is much more dense and compressed in the plains, than on the tops of mountains. For example, if the barometer, which stands at 27 inches in the plain, falls, on the top of a mountain, to 18, a difference of one third of the whole weight of the column of air, we say, that, the compression of this element being always proportioned to the incumbent weight, the air at the top of the mountain is, of course, one third less dense than that in the plain, because it is compressed by a weight one third less. But strong reasons concur in making me suspect the truth of this conclusion, which has hitherto been regarded as natural, and perfectly legitimate.

Let us, for a moment, abstract this compressibility of the air, which several causes may augment or diminish, destroy or compensate: Let us suppose the air to be every where equally dense; if its thickness exceeded not three leagues, it is certain, that, in mounting one league, the barometer, being loaded with one third less weight, would descend from 27 to 18 inches. Now the air though compressible, appears to me to be equally dense at all heights; and this opinion I shall support by the following facts and reasonings.

1. The winds are equally strong, and equally violent at the tops of the highest mountains

as in the lowest valleys. With regard to this fact all observers are agreed. Now, if the density of the air were one third less, the action of the wind would necessarily be one third weaker, and all the winds at the height of a league would be only zephirs, which is absolutely contradicted by uniform experience.

2. Eagles, and several other birds, not only fly to the tops of the highest mountains, but rise to great heights above them. Now, I ask if these animals could either fly, or even support themselves, in a fluid one third less dense than common air, and if the weight of their bodies, notwithstanding all their efforts, would not oblige them to sink lower?

3. All observers, who have climbed to the tops of the highest mountains, agree that they respire as freely as in any other situation, and that the only inconveniency they feel arises from the cold, which augments in proportion to the elevation. Now, if the air was one third less dense at the tops of mountains, the respiration of man, and of birds which mount still higher, would not only be injured, but stopped, as actually happens to animals in an air pump when one fourth or one third of the air contained in the receiver is exhausted.

4. As cold condenses as much as heat rarefies the air, and as, in proportion to the elevation of mountains, the cold increases, does it
not

not follow, that the degrees of condensation of the air correspond to the degrees of cold? This condensation may equal, and even surpass that of the air in plains, where the heat escaping from the internal parts of the earth is much greater than at the tops of mountains, which are the most advanced and coldest points on the surface of the globe. Hence this condensation of the air by cold, in high regions of the atmosphere, should compensate the diminution of density produced by a decrease of the incumbent weight; and, of course, the air should be equally dense on the cold summits of mountains as in the plains. I am even led to think, that the air is more dense on the tops of mountains, because there the winds seem to be more violent, and the birds which soar above the highest summits appear to support themselves in the air with more ease in proportion to the height they rise.

I may, therefore, conclude, that the free air is nearly of equal density at all heights, and that the atmosphere extends not so high as has been determined, by considering the air as an elastic mass compressed by an incumbent weight. Thus the total thickness of the atmosphere may not exceed three leagues, instead of from fifteen to twenty, as has been conjectured by philosophers *.

The

* Alhazen, from the duration of the twilights, pretended that
the

The first stratum of the atmosphere is filled with vapours exhaled from the surface of the globe, both by its own heat and that of the sun. In this stratum, which extends to the height of the clouds, the heat arising from exhalations produces and supports a rarefaction that forms an equipoise to the superior air; so that the lower stratum of the atmosphere is not so dense as it ought to be in proportion to the pressure it receives. But, at the height where this rarefaction ceases, the air undergoes all that condensation which is produced by the cold of this region, where the heat arising from the earth is much diminished; and this condensation appears to be even greater than that which might be produced, by the weight of the superior strata, in the inferior regions, which are supported by rarefaction. This idea is strengthened by another phenomenon, which is the height of the atmosphere is 44331 fathoms. Kepler, upon the same principle, makes it 41110 fathoms.

M. de la Hire, when treating of the horizontal refraction of 32 minutes, fixes the mean height of the atmosphere at 34585 fathoms.

M. Mariotte, from his experiments on the compressibility of air, makes the height of the atmosphere 30000 fathoms.

However, comprehending under the atmosphere that part of the air only in which refractions take place, M. Bouguer ascertains the height not to be above 5158 fathoms, i. e. two and a half or three leagues; and I believe that this result is more certain and better founded than any of the others.

is the condensation and suspension of the clouds in that elevated region where they are formed and supported. Beyond this middle region, where the cold and condensation commence, the vapours rise, but cease to be visible, except when a part of a cold stratum seems to be pushed back toward the surface of the earth, and when the heat escaping from the earth being for some time extinguished by rains, the vapours then collect and thicken around us in the form of mists and fogs. Without these circumstances, the vapours never become visible till they arrive at that region where the cold condenses them into clouds, and stops their further ascension: Their gravity, which augments in proportion as they become more dense, fixes them in an equilibrium which they cannot surmount. We perceive that the clouds are generally higher in summer, and still higher in warm climates. It is in this season and in these climates that the stratum formed by evaporation from the earth rises highest. On the contrary, in the frozen regions near the pole, where the evaporation produced by the heat of the globe is much less, the stratum of dense air seems to touch the surface, and there to retain the clouds, which never rise higher, but surround these gloomy regions with perpetual fogs.

III.

Of some Winds which have a regular variation:

THERE are certain climates and particular countries where the winds vary regularly; some at the end of six months, others in a few weeks, others from morning to night, and from night to morning. In Vol. I. p. 388. I remarked, That, at St Domingo, there are two different winds which rise regularly every day; the one, which is from the sea, comes from the east, and begins at 10 o'clock before noon; the other, which is a land-wind, rises at 6 or 7 in the evening, and continues the whole night. M. Fresnaye writes me, that my information has not been exact. 'The two regular winds,' he remarks, 'which blow at St Domingo, are both from the sea, and blow, the one in the morning from the east, and the other in the evening from the west, which is only the same wind returned. It is evidently occasioned by the sun; for, every man perceives that, between one and two o'clock after noon, a transient gust arises. When the sun declines, by rarefying the air on the west, it drives to the east the clouds which the morning wind had confined toward the opposite quarter. These

' These returned clouds, from April or May till
 ' toward autumn, produce in the district of Port-
 ' au-Prince the regular rains which constantly
 ' proceed from the east. There is not a single
 ' inhabitant who does not predict the evening
 ' rain between six and nine o'clock, when, accor-
 ' ding to their mode of expression, *the broken*
 ' *cloud has been sent back.* The west wind con-
 ' tinues not during the whole night. It falls
 ' regularly toward the evening; and, when it
 ' ceases, the clouds pushed from the east are en-
 ' abled to fall in the form of rain, as soon as their
 ' weight exceeds that of an equal column of air.
 ' The wind which prevails in the night is a land-
 ' wind, which proceeds neither from the east
 ' nor the west, but follows the projections of
 ' the coast. At Port-au-Prince, the south wind,
 ' because it traverses the course of the river, is
 ' intolerably cold during the months of January
 ' and February *.'

IV.

* Note communicated to M. de Buffon by M. Fresnaye,
 one of the counsellors of St Domingo, dated March 10. 1777

IV.

Of Lavanges, or great masses of Snow and Ice rolling down from high mountains.

IN high mountains, there are winds produced by accidental causes, and particularly by *lavanges* *. In the environs of the Alpine glaciers, several species of *lavanges* are distinguishable; some of them are called *windy lavanges*, because they produce a great wind. They are formed when a new fall of snow has been put in motion, either from melting below by the interior heat of the earth, or by the agitation of the air. The snow then forms itself into balls, and in rolling accumulates, falls in vast masses into the valleys, and produces a great agitation in the air; because the snow runs with rapidity, and in immense volumes, and the winds occasioned by the motion of these masses are so impetuous, that they overturn every thing, even the largest pines, that oppose their passage. These *lavanges* cover the whole territory over which they extend with a very fine snow; and this powdered snow rises in the air at the caprice of the winds, *i. e.* without any fixed direction, which is extremely dangerous

* I know no single English word expressive of this idea, and therefore retain the French term.

dangerous to people in the fields ; because they know not to what side to run in order to protect themselves ; for, in a few seconds, they find themselves surrounded, and often completely buried with the snow.

Another species of *lavanges*, still more dangerous than the first, is called by the country people Schlaglawen, *i. e.* *dashing* or *striking lavanges*. They proceed not with such rapidity as the first kind ; but they overturn every thing in their way, and carry along with them great quantities of earth, stones, flints, and even entire trees ; so that their passage from the mountain to the valley is a vast track of destruction and ruin. As they proceed with less rapidity than the *lavanges* composed of pure snow, they are more easily avoided. Their approach is announced at a distance ; for they shake the mountains and the valleys by their motion and weight, and produce a noise equal to that of thunder.

These tremendous effects may proceed from very slight causes : A small quantity of snow falling from a tree or a rock, the sound of bells, or the shock of a cannon or musket, provided they detach some portions of snow from the summit, which form into balls, and increase in magnitude as they descend, will accumulate into a mass as large as a small mountain before they arrive at the valley.

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The inhabitants of countries subject to *lavanges* have invented several precautions to prevent their destructive effects. They place their buildings opposite to small eminences, which may break the force of the *lavanges*. They likewise make plantations of wood before their habitations. At Mount St Godard, there is a forest in a triangular form, the acute angle of which is directed towards the mountain, and seems to have been planted with a view to turn off the *lavanges* from the village of Urseren and the buildings situated at the foot of the mountain; and every person is forbid, under the severest penalties, to injure the forest, which may be regarded as the safeguard of the village. With the same intention there are, in many places, walls erected with their acute angles turned toward the mountain. A wall of this kind may be seen at Davis, in the country of the Grisons, as also near the baths of Leuk or Louache in Valais. In the same country of the Grisons, and other places, there are, in the passages through the mountains, vaults at convenient distances, cut out of the rock on the side of the high-way, which serve passengers as places of refuge against the *lavanges* *.

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* Hist. Nat. Helvetique, par Scheuchzer, tom. 1. p. 155.

*ADDITIONS to the Article, Of Irregular
Winds, Water-spouts, &c. Vol. I. p. 386.*

I.

*Of the Violence of the South Winds in some North-
ern Countries.*

THE Russian voyagers have remarked, that, in the entry to the territory of Milim, there is, on the left of the river Lena, a great plain entirely covered with overturned trees, and that all these trees lie in a direction from south to north for an extent of several leagues; so that the whole district, formerly covered with trees, is now strewed with dead trunks in the above direction from south to north. This effect of the south winds has likewise been observed in other northern regions.

In Greenland, and particularly in the autumn, the winds are so impetuous, that the houses are often shaken to pieces, and the boats and tents carried up into the air. The Greenlanders even assure us, that, when they go out to secure their boats, they are obliged to creep on their bellies,

bellies, lest they should become the sport of the winds. The most violent tempests come from the south, turn to the north, and then terminate in a calm. It is on these occasions that the ice in the bays is raised from its bed, and dispersed in small portions over the ocean*.

II.

Of Water-Spouts.

M. de la Nux, whom I have often quoted, and who lived forty years in the isle of Bourbon, has had an opportunity of seeing a great number of water-spouts, and he has communicated to me his observations, of which the following is an abridgement.

The water-spouts observed by M. de la Nux were formed, 1. In calm days, and in those intervals when the wind passes from the south to the north; though he saw one, which was formed previous to this passage of the wind from one quarter to another, and even in the current of a north wind, *i. e.* a pretty long time before this wind had ceased: The cloud from which this water-spout depended, and to which it was attached, was still violently driven to the south. The sun, at the same time, was seen behind the

VOL. IX. I cloud

* Hist. gen. des Voyages, tom. 18. p. 22.

cloud to the south. It happened on the 6th day of January, about eleven o'clock before noon.

2. These water-spouts are formed during the day in detached clouds, apparently very thick, much longer than broad, and well defined below in the direction of the horizon: The under part of these clouds is always very black.

3. All these water-spouts at first appear under the form of inverted cones, whose bases are more or less extensive.

4. Several of those water-spouts that appear under the figure of inverted cones, are sometimes attached to the same cloud; some are never entirely completed; some are dissipated at a small distance from the cloud; and others descend apparently very near to the surface of the sea, under the form of a long flat cone, which is narrow and pointed at the bottom. In the centre of this cone, and through its whole length, there is a whitish transparent canal, about one third of the diameter of the cone, the two sides of which were very black, especially on their first appearance.

These water-spouts were observed from a point in the isle of Bourbon elevated 150 fathoms above the level of the sea, and they were generally three, four, or five leagues from the place of observation, which was the house of M. de la Nux.

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The following is a more particular description of these water-spouts.

When the end of the shaft, or top of the cone, which is then very sharp pointed, has descended about a fourth of the distance of the cloud from the sea, we begin to perceive on its surface, which is commonly calm and of a transparent whiteness, a small black circle, which is produced by the agitation and whirling of the water: In proportion as the point of this shaft descends, the water boils; this boiling increases in proportion as the point approaches toward the surface, and the water of the sea rises in successive whirlings to a greater or smaller height, which, in the largest water spouts, is about twenty-feet. The end of the shaft is always above this whirling, the size of which is proportioned to that of the water-spout which puts it in motion. The end of the shaft seems not to touch the surface of the sea, otherwise than by joining itself to the boiling or whirling which rises to meet it.

We sometimes see larger and smaller cones of water-spouts proceeding from the same cloud; some of them have the appearance of threads, and others are much larger. We often see ten or a dozen of small but complete water-spouts issuing from the same cloud, most of which are dissipated near their exit, and visibly ascend to the cloud. In this last case, the shaft suddenly

swells as far as the inferior extremity, and appears like a cylinder suspended from the cloud, torn in pieces below, and of a small extent.

The water-spouts with broad bases gradually enlarge through their whole extent, and likewise in the under end, which seems to recede from the sea and to approach the cloud. The agitation and whirling they produce in the water gradually diminishes, and the under part of the shaft soon enlarges and assumes nearly a cylindrical form. It is in this state that the two sides of the canal widen; and we then see the water rushing with rapidity, and in a spiral form, into the cloud. Lastly, the appearance of the water-spout terminates by the successive shortening of this species of cylinder.

The largest water-spouts remain longest without dissipating; and some of them continue more than half an hour.

A torrent of rain generally rushes out of the same part of the cloud from which the water-spouts issue, and some of them not unfrequently still adhere to the cloud; these torrents of rain often conceal water-spouts before they are dissipated. I perceived distinctly, M. de la Nux remarks, on the 26th of October 1755, a water-spout in the middle of one of these torrents, which became so great that it was soon concealed from my view.

The wind, or the agitation of the air below
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the cloud, breaks neither the large nor the small water-spouts; for this impulsion only declines them from the perpendicular. The smallest kinds form very remarkable curves, and even sinuosities. The extremity which terminates in the sea is often far removed from the direction of the other which is attached to the cloud.

We never see new water-spouts formed after rain has fallen from the clouds which produced them.

'On the 14th day of June 1756, about four o'clock afternoon, I was,' says M. de la Nux, 'on the margin of the sea, and above its level twenty or twenty-five feet. I saw twelve or fourteen water-spouts issue from the same cloud. Three of them only were considerable, and particularly the last. The canal in the middle of the cylinder was so transparent, that, as the sun shone, I saw the clouds behind it. The cloud which produced so many water-spouts extended nearly from south-east to south-west; and the large water-spout under consideration appeared in the south-south-west from my station. The sun was very low; for the days were then about the shortest. I saw no rain proceed from the cloud: Its height seemed to be from five to six hundred fathoms.'

The more the sky is obscured with clouds, water-spouts, and the phaenomena which accompany them, are the more easily observed.

M. de la Nux thinks, and perhaps with reason, that water-spouts are nothing but viscous portions of a cloud driven off by different whirlwinds, *i. e.* by the whirlings of the superior air sinking into the mass of vapours of which the whole cloud is composed.

What seems to prove that these water-spouts are composed of viscous parts, is the tenaciousness of their cohesion; for they make inflexions and curvatures in every direction, without breaking: If the matter of water-spouts was not viscous, how can we conceive that they should, without breaking, bend and obey the motion of the winds? If all the parts did not firmly adhere, the wind would dissipate them, or, at least, make them change their form. But, as the form, both of the large and small water-spouts, is uniformly the same, this is almost a certain indication of the viscous tenacity of the matter of which they are composed.

Thus the basis of the matter of water-spouts is a viscous substance contained in the clouds, and every water-spout is formed by a whirlwind of air pressing through the mass of vapours, and, by blowing up the inferior part of the cloud, pierces it, and descends with its covering of viscous matter. And, as complete water-spouts descend from the cloud to the surface of the sea, the water must boil and whirl at the place to which the end of the water-spout is directed; because

because the air blows from the extremity of the water-spout like the tube of a pair of bellows. The effects of this blowing upon the sea will augment, in proportion as the cylinder approaches the surface of the water; and, when the orifice of the tube enlarges, a greater quantity of air is permitted to escape, and the agitation of the water is, of course, increased.

It has been imagined, that water-spouts carried off and contained great quantities of seawater: The rains, or rather the spray, which often fall in the neighbourhood of water-spouts, have strengthened this prejudice. The canal in the middle of every species of water-spout is always transparent, on whatever side it is viewed. If the water of the sea seems to rise, it is not in this canal, but only on its sides. Almost every water-spout suffers inflections, and often in opposite directions, in the form of an S, the one end of which is in the cloud, and the other in the sea. Hence these water-spouts of which we have been treating, cannot contain water either to be poured into the sea, or raised to the cloud. Of course, they can be attended with no danger, except what proceeds from the impetuosity of the air which escapes from their inferior orifice; for we are assured by every person who has had an opportunity of observing these water-spouts, that they are solely composed of air confined in a viscous cloud, and determined

terminated by its whirling to the surface of the sea.

M. de la Nux has seen water spouts around the isle of Bourbon in the months of January, May, June, and October, *i. e.* in all seasons of the year. He has seen them in calm weather, and during the highest winds. These phaenomena, however, may be said to be rare, and seldom appear but upon the sea; because the viscosity of the clouds can only proceed from the bituminous and greasy particles raised, by the heat of the sun and the winds, from the waters of the sea, and collected in the clouds near its surface. It is for this reason that water-spouts seldom appear on land, where there is not, as on the surface of the sea, a sufficient quantity of bituminous and oily particles to be exhaled by the action of the sun. They are sometimes, however, observed on land, and even at great distances from the sea; this effect may be produced, when viscous clouds have been rapidly driven by a violent wind from the sea toward the land. M. Grignon, in the month of June 1768, saw a well formed water-spout in Lorrain near Vauvillier, among the hills which are a continuation of the Vosges. It was about fifty fathoms high. Its form was that of a column, and it communicated with a large thick cloud. It was impelled by one or several winds, which made the water-spout turn rapidly; and it produced lightning
and

and thunder. This water-spout continued seven or eight minutes only, and broke upon the base of the hill, which is from five to six hundred feet high *.

Water-spouts have been mentioned by several voyagers; but no man has examined them with such accuracy as M. de la Nux. For example, these voyagers tell us, that, when water-spouts are forming, a black smoke rises on the surface of the sea: This appearance, we are certain, is deceitful, and proceeds solely from the situation of the observer. If he is placed on a situation so elevated that the distance of the whirling excited in the water by the spout, exceeds not his sensible horizon, he will see nothing but the water rising and falling back in rains, without any mixture of smoke. This fact is apparent when the sun shines on the place where the phaenomenon happens.

These water-spouts have nothing in common with those agitations and smoke sometimes produced by submarine fires, and of which we have formerly treated. Water-spouts neither contain nor excite any smoke. They are every where rare: They are most frequent in the seas of warm climates, and where, at the same time, calms are common, and the winds are most inconstant. They are likewise more frequent, perhaps, near islands and coasts than in the open sea.

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* Note communicated by M. Grignon to M. de Buffon, Aug. 6. 1777.

ADDITIONS to the article, Of Earthquakes and Volcano's, Vol. I. p. 382.

I.

Of Earthquakes.

EARTHQUAKES are produced by two causes: The first is the sudden sinking of cavities in the bowels of the earth; and the second, which is still more frequent and more violent than the first, is the action of subterraneous fires.

When a cavern sinks in the middle of a continent, it produces a commotion which extends to a greater or smaller distance, in proportion to the quantity of motion excited by the fall of this mass of earth; and, if this mass is inconsiderable, or falls from no great height, it will not produce a succussion so violent as to be perceived at a great distance; the effect is limited to the neighbourhood of the sunk cavern; and if the movement is propagated to greater distances, it is only by slight tremblings or vibrations.

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As most of the primitive mountains rest upon caverns, because, at the moment of their consolidation, these eminences were blown up by the action of the internal fire, sinkings in the mountains have happened, and still happen, whenever the vaults of the caverns are undermined by water, or shaken by any convulsion. An entire portion of a mountain sometimes sinks perpendicularly, but oftener inclines, and not unfrequently reverses. Of this we have striking examples in several of the Pyrennees, where the strata, formerly horizontal, are often inclined more than forty-five degrees; which shows, that the entire mass of each portion of the mountain, whose strata were parallel to each other, has inclined by the lump, and, in the moment of its sinking, rested upon a base inclined to the horizon forty-five degrees. This is the most general cause of the inclination of strata in mountains. For the same reason, we often find, between the adjacent eminences, strata which descend from the first and rise to the second, after having traversed the valley. These strata are horizontal, and are bedded at the same height in the two opposite hills, between which the cavern had fallen in. The earth sinks down, and the valley is formed, without producing any other derangement than a greater or smaller inclination of the strata, according

according to the depth of the valley, or the declivity of the two opposite hills,

This is the only sensible effect of the sinking of caverns in mountains and other parts of continents. But, whenever this effect happens in the bottom of the sea, where sinkings must be more frequent than on the land, because the water perpetually undermines the vaults in every place where they support the bottom of the ocean, these sinkings not only derange and incline the strata, but sensibly lower the level of the sea. From the first occupation of the waters, their level has been depressed two thousand fathoms by these sinkings; and, as all the submarine caverns have not yet fallen in, it is more than probable, that the basin of the sea, by growing more and more deep, will lessen its surface, and, of course, that the extent of all the continents will always continue to augment by the retreat and sinking of the waters.

A second and more powerful cause than the first concurs in producing the same effect. This cause is the rupture and sinking of caverns by the action of submarine fires. It is certain, that no motion or sinking in the bottom of the sea can happen without diminishing its surface: And, if we consider the general effects of subterraneous fires, we will perceive that, as long as there is fire, the commotions of the earth will not be confined to simple tremblings; for the efforts of fire raise and open the sea and the land by

by violent and reiterated succussions, which not only overturn and destroy the adjacent lands, but shake those that are distant, and ravage or derange every thing in the route of their direction.

The earthquakes occasioned by subterraneous fires generally precede eruptions of volcano's, and sometimes cease the moment the fire opens a passage through the earth, and carries its flames into the air. These dreadful earthquakes sometimes continue during the whole time of eruptions. These two effects are intimately connected. There is never a great eruption of a volcano without being preceded, or at least accompanied, with an earthquake. But we often feel very violent succussions of the earth without any eruption of fire. Those movements in which fire has no part, proceed not only from the first cause, the falling in of caverns, but likewise from the action of subterraneous winds and storms. There are many examples of lands raised or sunk by the force of these internal winds. Sir William Hamilton, a man as respectable for his private character, as admirable for the extent of his knowledge and researches on this subject, told me that he had seen between Trente and Verona, near the village of Roveredo, several little hills composed of large masses of calcarious stones, which had evidently been raised by different explosions of subterraneous winds. There is no indication

indication of the action of fire upon any of these rocks or their fragments. The whole country, on both sides of the highway, for an extent of near a league, has, from place to place, been overturned by the prodigious efforts of subterraneous winds: The inhabitants say that it happened suddenly, and was the effect of an earthquake.

But the force of the wind, however violent, appears not to be a cause sufficient to produce such great effects; and, though there be no marks of fire in these little hills raised by the commotion of the earth, I am persuaded that they have been elevated by electrical explosions of subterraneous thunder, and that the internal winds have contributed to this effect solely by producing electrical storms in the cavities of the earth. Hence all convulsive movements of the earth may be referred to three causes: The first and most simple is the sinking of caverns; the second, storms and subterraneous thunder; and the third, the action of fire kindled in the interior parts of the globe. It is easy to ascribe to one or other of these three causes all the phaenomena which accompany or succeed earthquakes.

Commutations of the earth sometimes give rise to eminences; but they more frequently produce gulfs. On the 15th day of October 1773, a gulf opened in the territory of Induno, in the
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State of Modena, the cavity of which was more than four hundred fathoms wide by two hundred deep *. In 1726, a mountain of a considerable height, situated in the northern part of Iceland, was sunk in one night by an earthquake, and a very deep lake assumed its place. The same night, about a league and a half distant, an ancient lake, the depth of which was unknown, was entirely dried up, and its bottom raised in such a manner as to form a pretty high hill, which still exists †. In the seas in the neighbourhood of New Britain, M. Bougainville remarks, earthquakes have terrible effects on navigation. On the 17th of June, the 12th and 27th of July 1768, there were three earthquakes at Boero, and on the 22d of the same month, one at new Brittany. These earthquakes sometimes annihilate islands and known sandbanks, and sometimes create them ‡.

There are earthquakes which extend to great distances; but they are always longer than broad. One of the most considerable was that felt in Canada in the year 1663. It extended more than two hundred leagues in length and one hundred in breadth, *i. e.* more than twenty thousand superficial leagues. The effects of the last earthquake in Portugal, which happened in

* Journ. hist. et politique, Dec. 10. 1773, art. *Milan*.

† *Melanges interassians*, tom. 1. p. 159.

‡ *Voyage autour du Monde*, tom. 2. p. 278.

in our own time, were felt still farther. M. le Chevalier de Saint-Sauveur, King's commandant at Merucis, informed M. de Genfanne, that, when walking on the left margin of Jouante in Languedoc, the sky suddenly became very dark, and that, in a moment after, he perceived, at the foot of the hill which is situated to the right of that river, a terrible bright globe of fire: Immediately there arose from the bowels of the earth a considerable mass of rocks, and the whole chain of mountains split from Merucis to Florac, an extent of near six leagues. This rent, in some places, is more than two feet wide, and has partly fallen in *. There are other earthquakes which produce little or no commotion. Kolbe relates, that, on the 24th of September 1707, from eight to ten o'clock before noon, the sea rose upon the land at the Cape of Good Hope and descended seven times successively, and with such rapidity, that, from one moment to another, the place was alternately covered and left by the waters †.

With regard to the effects of earthquakes, the falling of mountains, and the sinking of caverns, I shall subjoin a few facts, which are both

* Hist. Nat. de Languedoc, par M. de Genfanne, tom. 1. p. 231.

† Descript. du Cap de Bonne-Esperance, tom. 2. p. 237.

both recent and well attested. In Norway, a whole promontory called *Hammersfields*, suddenly fell *. A very high mountain, near that of Chimborazo, one of the highest of the Cordeliers in the province of Quito, tumbled down in a moment. This fact, with all its circumstances, is related in the memoirs of M. de la Condamine and Bouguer. Similar fallings and sinkings often happen in the southern islands of India. At Gamma-canore, where the Dutch have a settlement, a high mountain fell suddenly in the year 1673, when the weather was fine : It was followed by an earthquake, which overturned the neighbouring villages, and destroyed several thousands of persons †. On the 11th of August 1772, in the island of Java and province of Cheribou, one of the richest settlements of the Dutch, a mountain, of about three leagues in circumference, suddenly sunk, and rose and sunk alternately like waves in a stormy ocean : It at the same time threw out many globes of fire, which were seen at a great distance, and gave a light as brilliant as that of day : All the plantations, together with about two thousand one hundred and forty inhabitants, without reckoning strangers, were entirely swallowed up ‡. We might recite many other examples of the sinking of

VOL. IX.

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* Hist. Nat. de Norwége, par Pontoppidan ; *Journal étranger*, Août 1755.

† Hist. gen. de Voyages, tom. 17. p. 54.

‡ See gazette de France, 21. Maii 1773, art. de la Haie.

lands and swallowing of mountains by the rupture of caverns, and the succussions occasioned by earthquakes and the action of volcanoe's: But we have said enough to establish the general conclusions we have drawn from the facts already related.

II.

Of Volcano's.

THE ancients have left us some notices concerning the volcano's which were known to them, and particularly those of *Ætna* and *Vesuvius*. Several learned and curious observers have in our days examined more minutely the form and effects of these volcano's. On comparing their descriptions, the first observation that presents itself, is the folly of transmitting to posterity the exact topography of these burning mountains. Their form may be said to change daily; their surface rises or sinks in various places; every eruption produces new gulfs or new eminences: To attempt to describe all these changes, is to follow and paint the successive ruins of a burning edifice. The *Vesuvius* of *Pliny*, and the *Ætna* of *Empedocles*, present very different aspects from those which have been so ably delineated by *Sir William Hamilton* and *Mr Brydone*; and, in a few a-

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ges, these recent descriptions will no longer resemble their objects. Next to the surface of the ocean, nothing on this globe is so fluctuating and inconstant as the surface of volcanic mountains: But even from this inconstancy, and from the variation of form and movements, some general conclusions may be drawn, by bringing particular observations under one point of view.

III.

Of the Changes which have happened in Volcano's.

THE base of *Ætna* is about sixty leagues in circumference, and its perpendicular height about two thousand fathoms above the level of the Mediterranean sea. We may, therefore, regard this enormous mountain as an obtuse cone, the superficies of which is not less than three hundred square leagues. This conical surface is divided into four zones, situated concentrically above each other. The first is the largest, and, by a gradual ascent, extends above six leagues from the most distant point at the foot of the mountain. This zone of six leagues broad is almost totally peopled and cultivated. The city of Catania and several villages are situated in this first zone, the surface of which

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exceeds

exceeds two hundred and twenty square leagues. The basis of this vast territory consists of various strata of ancient and modern lavas, that have run from different parts of the mountain, from which explosions of subterraneous fires have issued. The surface of this lava, mixed with ashes thrown out from different craters, is converted into a fine soil, which is now sown with grain and planted with vines, except in a few places where the lava is too recent, and still remains uncovered with earth. About the top of the zone, we still see several craters, more or less large and deep, from which the materials issued that have formed the upper stratum or soil.

The second zone commences at the termination of these six leagues. This second zone is an ascent of about two leagues broad. Its declivity is every where more rapid than that of the first zone; and this rapidity augments in proportion as you approach toward the summit. The surface of this second zone is about forty or forty-five square leagues: Its whole extent is covered with magnificent forests, and form a fine belt of verdure to the white and hoary head of this venerable mountain. The soil of these fine forests is nothing but lava and ashes converted by the operation of time into excellent earth. What is still more remarkable, the surface of this zone is so unequal, that it e-
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very where presents hills, or rather mountains; all of which have been produced by different eruptions from the summit of *Ætna*, and other craters below the summit, several of which have formerly acted in this very zone, now converted into forests.

Before arriving at the summit, and after having passed these fine forests, we traverse a third zone, which gives birth to small vegetables only. In winter, this region is covered with snow, which melts in summer. We afterwards meet with a line of permanent snow, which marks the commencement of the fourth zone, and extends to the top of the mountain. These snows and ice occupy about two leagues from the region of small vegetables to the summit, which is likewise covered with snow and ice. Its figure is an exact cone; and it contains the great crater of the volcano, from which are continually discharged immense volumes of smoke. The internal figure of the crater is that of an inverted cone. It is composed of nothing but ashes and other burnt matters thrown out by the mouth of the crater, which is in the centre of the volcano. The external surface of the summit is very rough. The snow is covered with ashes, and the cold is very piercing. On the north side of this region of snow, there are several small lakes which never freeze. In general, the surface of this last zone is pretty
K 3 equal;

equal, and observes the same declivity, except in a few places ; and it is below this region only where we meet with a great number of inequalities, eminences, and hollows produced by eruptions, and where we see hills and mountains more or less recently formed, and composed of burnt matters rejected by these different mouths or craters.

In 1770, according to Mr Brydone, the crater on the top of *Ætna* was more than a league in circumference ; and very different dimensions have been ascribed to it both by ancient and modern authors. All these authors, however, were right ; for the dimensions of this mouth of fire have undergone many alterations. All we can infer from the various descriptions that have been given of it, is, that the crater with its margins have been four times overturned within these six or seven hundred years. The materials of which it is composed fall back into the bowels of the mountain, are again rejected by fresh eruptions, and form a new crater, which augments and rises by degrees, till it again falls back into the great gulf of the volcano.

The top of the mountain is not the only place from which the subterraneous fire has been discharged. Through the whole territory which forms the sides and ridge of *Ætna*, and at great distances from the summit, there are many
craters

craters which give passage to the fire, and which are surrounded with broken rocks that had been discharged by different eruptions. We may even reckon several hills formed by the eruptions of these small volcano's which surround the great one. Each of these hills has a crater at its top, in the centre of which is a deep mouth or gulf. Every eruption of *Ætna* has produced a new mountain; and, perhaps, Mr Brydone remarks, their number would determine, better than any other method, that of the eruptions of this famous volcano.

The city of Catania, which is situated at the foot of Mount *Ætna*, has often been laid in ruins by the lavas which issued from these new mountains during the time of their formation. In ascending from Catania to Nicolosi, we traverse twelve miles through a country formed by ancient lavas, where we see the mouths of extinguished volcano's, which at present are fertile lands, covered with grass, corn, and vineyards. The lavas which form this region proceeded from the eruptions of the small mountains, which are every where dispersed over the sides of *Ætna*: They are all without exception, either regular hemispheres or cones. In general, every eruption raised one of these mountains. Hence the action of the subterraneous fires does not always reach the summit of *Ætna*. They often issue from the sides, and even from
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the foot of this burning mountain. Each eruption from the sides of *Ætna* commonly produces a new mountain composed of rocks, stones, and ashes projected to a great distance by the force of the fire ; and the magnitude of these new mountains is proportioned to the duration of the eruption. If it continues but a few days, it produces only a little hill, about a league in circumference at the base, and three or four hundred feet in perpendicular height. But, if the eruption continues some months, like that of 1669, it then gives rise to a considerable mountain of two or three leagues in circumference, and nine hundred or a thousand feet high ; and all these hills produced by *Ætna*, some of which are twelve thousand feet high, appear only as small elevations intended to accompany the majesty of the parent mountain.

In *Vesuvius*, which is a very small volcano when compared with *Ætna*, eruptions from the sides of the mountain are rare, and the lava generally issues from the crater at the summit. But, in *Ætna*, eruptions more frequently proceed from the sides than the top, and lava issues abundantly from every new mountain formed by these eruptions. Mr Brydone, according to the information he received from M. Recupero, says, that the masses of stones projected from *Ætna* rise to such a height that they take twenty-one seconds of time in descending to the
the

the earth ; while those of Vesuvius fall in nine seconds ; hence the stones projected by Vesuvius rise to the height of 1215 feet, and those projected by *Ætna* rise 6615 feet ; from which we may conclude, if the observations be accurate, that the force of *Ætna* is to that of Vesuvius as 441 to 81, *i. e.* five or six times greater. That Vesuvius is a very feeble volcano, when compared to *Ætna*, is proved in a more forcible manner by this circumstance, that *Ætna* has actually produced other volcano's, which are larger than that of Vesuvius.

‘ Not a great way from this cavern, are two
 ‘ of the most beautiful mountains of all that
 ‘ number that spring from *Ætna*. I mounted
 ‘ one of our best mules, and with a good deal
 ‘ of difficulty arrived at the summit of the high-
 ‘ est of them, just a little before sun-set. The
 ‘ prospect of Sicily, with the surrounding sea
 ‘ and all its islands, was wonderfully noble. The
 ‘ whole course of the river Semetus, the ruins
 ‘ of Hybla, and several other ancient towns ;
 ‘ the rich corn-fields and vineyards on the low-
 ‘ er region of the mountain, and the amazing
 ‘ number of beautiful mountains below, made a
 ‘ delightful scene. The hollow craters of these
 ‘ two mountains are each of them considerably
 ‘ larger than that of Vesuvius. They are now
 ‘ filled with stately oaks, and covered to a great
 ‘ depth with the richest soil. I observed that
 ‘ this

‘ this region of *Ætna*, like the former, is composed of lava ; but this is now covered so deep with earth, that it is no where to be seen, but in the beds of the torrents. In many of these it is worn down by the water to the depth of fifty or sixty feet, and in one of them still considerably more. . . . This conical mountain is of a very great size ; its circumference cannot be less than ten miles. Here we took a second rest, as the greatest part of our fatigue still remained. The mercury had fallen to $20 : 4\frac{1}{2}$. —We found this mountain excessively steep ; and although it had appeared black, yet it was likewise covered with snow. . . . The present crater of this immense volcano is a circle of about three miles and a half in circumference. It goes shelving down on each side, and forms a regular hollow like a vast amphitheatre. From many places of this space, issue volumes of sulphureous smoke, which, being much heavier than the circumambient air, instead of rising in it, as smoke generally does, immediately on its getting out of the crater, rolls down the side of the mountain like a torrent, till coming to that part of the atmosphere of the same specific gravity with itself, it shoots off horizontally, and forms a large track in the air, according to the direction of the wind ; which, happily for us, carried it exactly to the side opposite to that where we were placed. The

'The crater is so hot, that it is very dangerous,
 'if not impossible, to go down into it; besides,
 'the smoke is very incommodious, and, in
 'many places, the surface is so soft, there have
 'been instances of people sinking down in it,
 'and paying for their temerity with their lives.
 'Near the centre of the crater is the great mouth
 'of the volcano. . . . When we arrived at the
 'foot of the cone, we observed some rocks of
 'an incredible size, that have been discharged
 'from the crater. The largest that has been
 'observed from Vesuvius, is a round one of a-
 'bout twelve feet in diameter. These are much
 'greater; indeed almost in proportion of the
 'mountains to each other.'

As all that region from the top of *Ætna*, to
 the distance of two leagues below, presents an e-
 qual surface, without hills or valleys, and as the
 ruins of *Empedocles* the philosopher's tower,
 who lived four hundred years before the Chri-
 stian aera, are still to be seen, it is probable, that,
 during all this period, the great crater has made
 few or no eruptions. Hence the force of the
 fire has diminished, as it no longer acts with vio-
 lence at the summit, and as all the modern e-
 ruptions have happened in the lower regions of
 the mountain. However, within these few cen-
 turies, the dimensions of the great crater have
 been often changed, as appears from the mea-
 surements of Sicilian authors at different periods.

Sometimes

Sometimes it falls down, and is again gradually elevated till it falls afresh. The first of these fallings, which are well attested, happened in the year 1157, a second in 1329, a third in 1444, and the last in 1669. But, from these facts we should not conclude, as Mr Brydone has done, that the crater will soon suffer another overthrow. The notion, that this effect should be produced every hundred years, seems to have no foundation. I should rather imagine, that, as the fire no longer acts with violence at the summit, its force has diminished, and will continue to diminish, in proportion as the sea retires: It has already retired several miles by the action of the volcano, which has formed large banks and bulwarks by vast torrents of lava. Besides, we know, from the diminished rapidity of Scylla and Charybdis, and several other indications, that the Sicilian sea has sunk considerably within these two thousand five hundred years. We may, therefore, conclude that this sea will continue to sink, and, of course, that the action of the neighbouring volcano's will not relax; so that the crater of *Ætna* may remain during a long time in its present state; and, if ever it falls back into the gulf, it will probably be for the last time. I farther presume, that *Ætna* ought to be regarded as one of the primitive mountains, on account of its height and the immensity of its size, and that it began to act at the remote

mote period when the waters first retreated. Its action, however, ceased after this retreat, and was not renewed till that modern period when the Mediterranean sea, being elevated by the rupture of the Bosphorus and the Straits of Gibraltar, deluged the land between Sicily and Italy, and approached to the basis of *Ætna*. Perhaps the first of these eruptions is still posterior to this epoch of Nature. 'It is evident,' Mr Brydone remarks, 'that *Ætna* did not burn in the days of Homer, nor for a long time before, otherwise it would have been impossible that this poet should have talked so much of Sicily, without mentioning an object so astonishing.' This remark of Mr Brydone is extremely just; and, of course, the first known eruptions of *Ætna* should be dated after the age of Homer. But we perceive, from the poetical allusions of Pindar and Virgil, and from the descriptions of ancient and modern authors, that, in the space of eighteen or nineteen centuries, the whole face of this mountain and of the adjacent country has been changed by earthquakes, eruptions, torrents of lava, and the formation of hills and gulfs by these commotions. For the facts above related I am indebted to Mr Brydone's excellent performance; and I have too high an esteem for Mr Brydone to believe that he can be offended, because I do not agree with him as to the force of volcano's, and some other conclusions he

he has drawn from these facts. No preceding author has observed with equal acuteness, or presented such lively pictures of the objects he surveyed; the whole republic of letters, therefore, ought to unite in celebrating a work so deserving of praise.

Torrents of glass in fusion, which have received the denomination of lavas, are not the first effects of eruptions. These eruptions are commonly announced by an earthquake more or less violent, which is the first effort of the subterraneous fire to escape from the bowels of the earth; It soon, however, opens a passage, which it enlarges by projecting rocks and every other obstruction to its motion. These materials, which are exploded to a great height, fall back upon each other, and form an eminence more or less considerable in proportion to the duration and violence of the eruption. As all the rejected matters are penetrated by fire, and most of them converted into burning ashes, the eminence to which they give rise is a mountain of solid fire, in which a great part of the matter is melted by the fervency of the heat. This melted matter soon begins to run, and generally flows to the foot of the new mountain by which it was produced. But, in small volcano's, which have not force sufficient to throw the ejected matters to a great distance, the lava issues from the top of the mountain. This effect is conspicuous in the eruptions

ruptions of Vesuvius. The lava rises in the centre of the crater. The volcano first throws out stones and ashes, which fall perpendicularly back into the old crater and augments its size. It is through this additional matter, which has fallen back, that the lava opens a passage. These two effects, though different in appearance, are nevertheless the same; for, in a small volcano, which, like Vesuvius, has not force enough to give birth to new mountains by projecting its materials to a distance, the whole fall back upon the summit and increase its height; and it is at the foot of this new crown of matter that the lava forces its way and flows down the mountain. This last effort is generally succeeded by a repose of the volcano. The succussions of the earth within, and the projections without, cease as soon as the lava flows. But the torrents of this glass in fusion produce effects still more extensive and disastrous than the convulsions of the mountain during an eruption. These rivers of fire ravage, destroy, and disfigure the surface of the earth. Nothing can oppose their dreadful progress. Of this the unfortunate inhabitants of Catania have had fatal experience. As their city had often been destroyed, either wholly or in part, by these torrents of lava, they built very strong walls of fifty-five feet in height. Surrounded by these ramparts, they believe themselves to be safe. The walls, it is true, resisted the heat

heat and the weight of the torrent. But this resistance served only to dam up the lava, which rose above the ramparts, fell back upon the city, and ravaged ever thing in its progress.

These torrents of lava are often half a league, and sometimes even two leagues broad.

‘ The last lava we crossed before our arrival at Catania, is of a vast extent. I thought we never should have done with it; it certainly is not less than six or seven miles broad, and appears in many places to be of an enormous depth.

‘ When we came near the sea, I was desirous to see what form it had assumed in meeting with the water. I went to examine it, and found it had driven back the waves for upwards of a mile, and had formed a large black high promontory, where before it was deep water. This lava, I imagined, from its barrenness, for it is as yet covered with a very scanty soil, had run from the mountain only a few ages ago; but was surprised to be informed by Signior Recupero, the historiographer of *Ætna*, that this very lava is mentioned by Diodorus Siculus to have burst from *Ætna* in the time of the second Punic war, when Syracuse was besieged by the Romans. A detachment was sent from Taurominum to the relief of the besieged. They were stopped on their march by this stream of lava, which having reached the sea before their arrival at the foot of the mountain,

' mountain, had cut off their passage; and obli-
 ' ged them to return by the back of Ætna, up-
 ' wards of 100 miles about. His authority for
 ' this, he tells me, was taken from inscriptions
 ' on Roman monuments found on this lava,
 ' and that it was likewise well ascertained by
 ' many of the old Sicilian authors. Now, as
 ' this is about 2000 years ago, one would have
 ' imagined, if lavas have a regular progress in
 ' becoming fertile fields, that this must long a-
 ' go have become at least arable; this however
 ' is not the case, and it is as yet only covered
 ' with a very scanty vegetation, and incapable
 ' of producing either corn or vines. There are
 ' indeed pretty large trees growing in the cre-
 ' vices, which are full of a rich earth; but in
 ' all probability it will be some hundred years
 ' yet, before there is enough of it to render this
 ' land of any use to the proprietors.

' We passed the river Alcantara on our way
 ' to Piedmonte, over a large bridge built entire-
 ' ly of lava; and near to this the bed of the ri-
 ' ver is continued for a great way, through
 ' one of the most remarkable, and probably one
 ' of the most ancient lavas that ever run from
 ' Ætna. In many places the current of the river,
 ' which is extremely rapid, has worn down the
 ' solid lava to the depth of 50 or 60 feet. Re-
 ' cupero, the gentleman I have mentioned, who
 ' is engaged in writing the natural history of
 VOL. IX. L Ætna,

' Ætna, tells me, he had examined this lava
 ' with great attention, and he thinks that its
 ' course, including all its windings, is not less
 ' than 40 miles. It issued from a mountain on
 ' the north side of Ætna, and finding some val-
 ' leys that lay to the east, it took its course that
 ' way, interrupting the Alcantara in many
 ' places, and at last arrived at the sea not far
 ' from the mouth of that river.

' The city of Jaci or Aci, and indeed all the
 ' towns on this coast, are founded on immense
 ' rocks of lava, heaped one above another, in
 ' some places to an amazing height; for it ap-
 ' pears that these flaming torrents, as soon as
 ' they arrived at the sea, were hardened into
 ' rock, which not yielding any longer to the
 ' pressure of the liquid fire behind, the melted
 ' matter continuing to accumulate, formed a
 ' dam of fire, which, in a short time, run over
 ' the solid front, pouring a second torrent into
 ' the ocean: This was immediately consolidated,
 ' and succeeded by a third, and so on. . . . The
 ' road from Jaci to this city is entirely over la-
 ' va, and consequently very fatiguing and
 ' troublesome. Within a few miles of that
 ' place, we counted eight mountains formed by
 ' eruptions, with every one its crater, from
 ' whence the burnt matter was discharged. Some
 ' of these are very high, and of a great compass.
 ' It appears evidently, that the eruptions of
 ' Mount

' Mount Ætna have formed the whole of this
 ' coast, and in many places have driven back
 ' the sea for several miles from its ancient bound-
 ' ary. . . At Catania, near to a vault, which is
 ' now thirty feet below ground, and has prob-
 ' ably been a burial place, there is a draw-well,
 ' where there are several strata of lavas, with
 ' earth to a considerable thickness over the sur-
 ' face of each stratum. Recupero has made use
 ' of this as an argument to prove the great an-
 ' tiquity of the eruptions of his mountain. For
 ' if it requires two thousand years or upwards
 ' to form but a scanty soil on the surface of a
 ' lava, there must have been more than that
 ' space of time betwixt each of the eruptions
 ' which have formed these strata. But what
 ' shall we say of a pit they sunk near to Jaci, of
 ' a great depth? They pierced through seven
 ' distinct lavas one under the other, the surfaces
 ' of which were parallel, and most of them co-
 ' vered with a thick bed of rich earth. Now,
 ' says he, the eruption which formed the lowest
 ' of these lavas, if we may be allowed to reason
 ' from analogy, must have flowed from the
 ' mountain at least 14,000 years ago. . .

' The great eruption of 1669, after shaking
 ' the whole country around for four months,
 ' and forming a very large mountain of stones
 ' and ashes, burst out about a mile above Monpe-
 ' lieri, and descending like a torrent, bore directly

' against the middle of that mountain, and (they
 ' pretend) perforated it from side to side: This
 ' however I doubt, as it must have broken the
 ' regular form of the mountain, which is not
 ' the case. But certain it is, that it pierced it
 ' to a greath depth. The lava then divided in-
 ' to two branches; and surrounding this moun-
 ' tain, joined again on its south side; and lay-
 ' ing waste the whole country betwixt that and
 ' Catania, scaled the walls of that city, and
 ' poured its flaming torrent into the ocean. In
 ' its way, it is said to have destroyed the posses-
 ' sions of near 30,000 people, and reduced them
 ' to beggary. It formed several hills where
 ' there were formerly valleys, and filled up a
 ' large lake, of which there is not now the least
 ' vestige to be seen. . . . There is no part of the
 ' coast from Catania to Syracuse nearer than
 ' thirty miles to its summit; and yet there has
 ' hardly been any great eruption, where the
 ' lava has not reached the sea, and driven back
 ' its waters to a great distance, leaving high
 ' rocks and promontories, that for ever set its
 ' waves at defiance, and prescribe their utmost
 ' limits. What a tremendous scene must the
 ' meeting betwixt these adverse elements have
 ' formed?

' We may easily conceive the variety of
 ' changes this coast has undergone in the space
 ' of some thousands of years, as every great e-
 ' ruption

‘ruption must have made a considerable difference.—Virgil is wonderfully minute and exact in his geography of Sicily; and this is the only part of the island that seems to be materially altered since his time. He says there was a very large port at the foot of *Ætna*, where ships were secure from every wind;

“*Portus ab accessu ventorum immotus et ingens;*”

‘of which, at present, there are not the least remains. It is probably the same that was called by the Sicilians the port of Ulysses; which is often mentioned by their writers.—The place of its existence is still shewn betwixt three and four miles up the country, amongst the lavas of *Ætna*. . . .

‘The circumference of the great base of *Ætna*, *Recupero* told me, he had been at a good deal of pains to ascertain; as it had generally been computed only at a hundred miles, or little more, although the radii of that circle had ever been esteemed at thirty of those miles; an absurdity in computation that had put him upon making this inquiry. The result was, that taking the supposed distances of one place from another, all the way round, the sum of the whole amounted to one hundred and eighty-three miles: An immense circle surely, and which is still enlarged by every considerable eruption.’

Here we have a territory of about 300 superficial leagues, all covered or formed by the projections of volcano's. In this territory, independent of the peak of *Ætna*, there are many other mountains, all of which are furnished with craters, and exhibit an equal number of particular volcano's. *Ætna*, therefore, must not be regarded as a single volcano, but as an assemblage of volcano's, the greater part of which are extinguished, or burn with a gentle fire, and a few of them still act with violence. At present, the summit of *Ætna* throws out nothing but smoke; and there seems to have been no eruption from it for a very long period of time; because it is surrounded, to the distance of two leagues, with an equal surface, and below this high region covered with snow, we find a large zone of vast forests, the soil of which is a fertile earth of several feet in thickness. This inferior zone is interspersed with inequalities, and presents heights, valleys, hills, and even pretty large mountains. But, as almost the whole of these inequalities are covered with a great thickness of earth, and as a long succession of time was necessary to convert volcanic matters into vegetable soil, we should regard the summit of *Ætna*, and the other mouths which surround it to the distance of four or five leagues, as volcano's almost extinct, or, at least, stifled for a number of ages; for all the eruptions, the dates
of

of which can be ascertained for two thousand five hundred years, have happened in the lower region, *i. e.* five, six, or seven leagues distant from the summit. The volcano's of Sicily seem to have had two different ages: The first very ancient, when the summit of *Ætna* began to act, and when the universal ocean left this summit dry, and sunk some hundreds of fathoms below: It was at this period that the first eruptions happened, which produced lava at the summit, and gave rise to those hills found below in the region of forests; but afterwards, the waters continuing to sink, they totally abandoned this mountain, as well as all the territories of Sicily and the adjacent continents. After this total retreat of the waters, the Mediterranean was only a lake of a moderate extent, and its waters were very distant from Sicily, and all the countries whose coasts it now washes. During all this time, which lasted several thousand years, Sicily was perfectly tranquil: *Ætna*, and the other ancient volcano's which surround its summit, had ceased to act; and it was not till after the augmentation of the Mediterranean by the waters of the ocean and of the Black sea, *i. e.* after the rupture of the straits of Gibraltar and of the Bosphorus, that the waters attacked the bases of the new mountains of *Ætna*, and produced those modern eruptions which have happened since the age of Pindar to the present time;

time; for this poet is the first author who has taken notice of eruptions of volcano's in Sicily. Vesuvius was precisely in the same situation: It was long one of the extinguished volcano's of Italy, which are very numerous; and their eruptions were not renewed till after the waters of the Mediterranean were increased and reached the bases of these inflammable mountains. The memory of the first eruptions, and even of all those which preceded the age of Pliny, was entirely obliterated. Neither should this circumstance excite surprise; for ten thousand years have, perhaps, elapsed since the general retreat of the waters to the augmentation of the Mediterranean, and an equal portion of time from the first eruption of Vesuvius till their removal. All these considerations seem to prove, that subterraneous fires cannot act with violence, unless when they are so near the sea as to receive a shock from a great body of water. This reasoning is confirmed by other phaenomena: Volcano's sometimes throw out great quantities of water, and likewise torrents of bitumen. P. de la Torr , an able philosopher, relates, that, on the 10th of March 1755, an immense torrent of water issued from the foot of the mountain, which deluged the neighbouring country. This torrent brought down such a quantity of sand, that it covered an extensive plain. These waters were very hot. The stones and sand left on the plain differed

differed not from those found in the sea. The torrent of water was immediately followed by another of inflamed matter, which proceeded from the same opening*.

The same eruption, 1755, was preceded, says M. D'Arthenay, by an inflammation so great, that it illuminated more than twenty-four miles of country along the coasts of Catania. The explosions were soon so frequent, that, on the 3d of March, we perceived a new mountain in the top of the old summit, in the same manner as lately happened to Vesuvius. Lastly, the magistrates of Mascali informed us, that, on the 9th of the same month, the explosions were terrible; that the whole sky was darkened with smoke; that, on the approach of night, it began to rain a deluge of small stones, some of which weighed three ounces, and covered all the adjacent cantons; that this tremendous rain continued an hour and a quarter, and was succeeded by another of black ashes, which lasted the whole night; that next day, about eight o'clock in the morning, the summit of *Ætna* threw out a river of water, which, for magnitude, might be compared to the Nile; that the most ancient and rugged mountains of lava were in an instant converted by this torrent into a vast plain of sand; that the water, which
for-

* Hist. du Mont Vésuve, par le P. J. M. de la Torré;
Journal étranger, mois Janvier 1576, p. 203.

fortunately ran not above half a quarter of an hour, was very hot; that the stones and sand carried along with it differed not from those of the sea; that, after this inundation, there issued from the same mouth a small rivulet of fire, which flowed during twenty-four hours; that, on the 11th, about a mile below this mouth, a rent happened through which issued a stream of lava, of about a hundred fathoms broad by two miles in length, and that it continued its course through the country the same day in which M. D'Arthenay wrote this relation *.

Let us attend to what Mr Brydon has remarked concerning this eruption. 'Part of the
' fine forests which compose the second region
' of *Ætna* was destroyed by a very singular event,
' not later than the year 1755. During
' an eruption of the volcano, an immense torrent
' of boiling water issued, as is imagined,
' from the great crater of the mountain, and in
' an instant poured down to its base; overwhelming
' and ruining every thing it met with
' in its course. Our conductors shewed us the
' traces of this torrent, which are still very visible;
' but are now beginning to recover verdure and
' vegetation, which for some time appeared to
' have been lost. The track it has left seems
' to

* Mem. des Savans étrangers, imprimés comme suite des mem. de l'acad. des sciences, tom. 4. p. 147.

' to be about a mile and a half broad ; and in
' some places still more.

' The common opinion, I find, is, that this
' water was raised by the power of suction,
' through some communication betwixt the vol-
' cano and the sea ; the absurdity of which is
' too glaring to need a refutation. The power
' of suction alone, even supposing a perfect va-
' cuum, could never raise water to more than
' thirty-three or thirty-four feet, which is e-
' qual to the weight of a column of air the whole
' height of the atmosphere.'

I must here observe, that Mr Brydone seems to have deceived himself ; for he confounds the force arising from the weight of the atmosphere with the force of suction produced by the action of fire. The force of the air, when a vacuum is made, is indeed limited to thirty-four feet. But the force of suction by fire has no limits : It is always proportioned to the quantity and intensity of the heat by which it is produced, as is evident from the common effects of blast furnaces. Hence the opinion of the *enlightened people of the country*, instead of being absurd, seems to be well founded. It is necessary that the cavities of volcano's should communicate with the sea : Without this communication, such immense torrents of water could not be thrown out, nor indeed could any eruption ever happen ; for no power, except the

the shock produced by the mingling of fire and water, could give rise to such violent effects.

The volcano of Pacayita, called the *water volcano* by the Spaniards, in all its eruptions, throws out torrents of water. The last eruption, in the year 1773, destroyed the city of Guatemala, and the torrents of water and lava descended to the South Sea.

With regard to Vesuvius, it has been remarked, that a wind, which blows from the sea, penetrates into the mountain. The noise it makes in certain cavities is heard, as if some torrent passed below : This noise ceases whenever the land winds blow, and, at the same time, the exhalations from the mouth of Vesuvius become less considerable. But, when the wind blows from the sea, this noise which resembles that of a torrent, recommences, and the exhalations of flame and smoke increase. The water of the sea, by thus insinuating itself into the mountain, sometimes in greater, and sometimes in smaller quantities, is the reason why this volcano has often thrown out both ashes and water *.

The learned M. D'Arthenay, who has compared the modern with the ancient state of Vesuvius, relates, that, during the interval which preceded the eruption 1631, the funnel or crater

* Descript. historique et philos. de Vesuve, par M. l'Abbé Mecatti ; *journal étranger*, mois Oct. 1754.

ter of the mountain was covered with trees and verdure ; that the small plain which bounds it produced excellent pasture ; that, in departing from the superior margin of the crater, we have a mile to descend before we arrive at this plain, in the middle of which was another gulf. We descended this gulf about a mile, by narrow and winding roads of an equal declivity, which led into a vast space surrounded with caverns, from whence there issued *winds so impetuous and so cold, that it was impossible to endure them.* According to the same observer, the summit of Vesuvius was then five miles in circumference. We should not, therefore, be surprised, that some philosophers have maintained that what seems now to be two mountains, was formerly one ; that the volcano was in the center, but that the south side, having fallen by the force of some eruption, produced the valley which separates Vesuvius from Mount Somma *.

M. Steller remarks, that the volcano's in the north of Asia are almost always *isolated*; that they have nearly the same surface ; and that there are always lakes on the summits, and hot waters at the foot of those mountains whose volcano's are extinct. This, he adds, is a farther proof of the correspondence established by Nature between the sea, mountains, volcano's, and hot waters.

* Observ. sur le Vésuve, par M. d'Arthenay ; *Journal de Savans étrangers*, tom. 4. p. 147.

waters. We find many springs of hot water in different parts of Kamtschatka *. In the island of Sjanw, forty leagues distant from Ternate, there is a volcano, which often throws out water, ashes †, &c. But it is unnecessary to accumulate more facts to prove the communication of volcano's with the sea. The violence of their eruptions would be sufficient to justify the presumption; and the general fact, that all acting volcano's are situated near the sea, completes the demonstration. However, as some philosophers have denied the reality and even the possibility of this communication of volcano's with the sea, I shall mention another fact related by M. de la Condamine, a man equally enlightened as worthy of credit. 'On the 14th
' of June 1755,' he remarks, 'I mounted to
' the summit of Vesuvius, and even to the brink
' of the funnel formed round the mouth of the
' volcano by its last explosion; and I perceived
' in the gulf, about forty fathoms deep, a
' great cavity resembling a vault toward the
' north of the mountain. I threw down large
' stones into this cavity, and counted twelve
' seconds before the noise of their rolling ceased. At the end of their fall I heard a noise
' similar to that of a stone falling into a mire;
' and, when nothing was thrown in, I heard a
' noise

* Hist. gen. des voyages, tom. 19. p. 238.

† Ibid. tom. 17. p. 54.

'noise like that of agitated waves †.' If the fall of the stones had been perpendicular, and met with no obstacle, twelve seconds would have given a depth of 2160 feet, and the bottom of the gulf would, on this supposition, be deeper than the level of the sea; for, according to le P. de la Torr , in 1753 this mountain was only 1677 feet above the surface of the sea, and this elevation has been diminished since that period. Hence we may conclude, that the caverns of this volcano descend below the level of the sea, and, of course, they may have subterraneous communications.

On the 15th of July 1753, I received, from an eye-witness, and an accurate observer, a distinct detail of the then condition of Vesuvius. I shall subjoin it in the words of the author, because it will tend to fix our ideas concerning what is to be farther apprehended from the effects of this volcano, the force of which seems to be greatly diminished.

'Having arrived at the foot of the mountain, which is about two leagues distant from Naples, we mounted during an hour and a half upon asses, and an equal portion of time was employed in completing the journey on foot. This is the steepest and most fatiguing part of the way. We held by the belts of two men
'who

† Voyage en Italie, par. M. de la Condamine; *Mem. de l'Acad. des Sciences*, ann e 1757, p. 371.

‘ who went before, and we climbed among ashes and stones formerly exploded.

‘ In our ascent, we saw the lavas of different eruptions. The most ancient, whose age is uncertain, but tradition assigns it two hundred years, is of an iron-gray colour, and has all the appearance of a stone: It is used for paving the streets of Naples, and in other works of masonry. We found others, which were said to be sixty, forty, and twenty years old. The last was thrown out in the year 1752. . . These different lavas, except the most ancient, when viewed at a distance, have the appearance of a blackish brown rugged earth, more or less recently laboured. When viewed nearer, it is a matter perfectly similar to the refuse of iron founderies. It is more or less composed of earth and ferruginous matter, and approaches more or less to the nature of stone.

‘ When arrived at the top, which before the eruption was solid, we find the first basin, whose circumference is said to be two Italian miles, and its depth appears to be about forty feet. It is surrounded with a crust of earth, which gradually thickens toward the base, and its upper margin is two feet broad. The bottom of this basin is covered with a greenish yellow sulphureous matter, which is hard and warm, but does not burn; and smoke issues through different fissures.

• In

‘ In the centre of this basin, we see a second,
 ‘ which is about half the circumference and half
 ‘ the depth of the former. Its bottom is co-
 ‘ vered with a blackish brown matter, similar to
 ‘ the freshest lavas we find on the road.

‘ In the second basin, there is a small mount
 ‘ which is hollow internally, open at the top,
 ‘ and likewise open from the top to the base to-
 ‘ ward that side of the mountain where we a-
 ‘ scended. This lateral opening is about twenty
 ‘ feet broad at the top, and four feet at the base.
 ‘ The height of this small mount is about forty
 ‘ feet; the diameter of the base is about as
 ‘ much, and that of the opening at the top a-
 ‘ bout twenty feet.

‘ This base rises about twenty feet above the
 ‘ second basin, and forms a third basin, which
 ‘ is filled with a liquid and burning matter, and
 ‘ has a perfect resemblance to the melted metal
 ‘ in an iron furnace. This matter perpetually
 ‘ boils with great violence. Its movements have
 ‘ the appearance of a lake moderately agitated,
 ‘ and the noise it produces is similar to that of
 ‘ waves.

‘ Every minute, quantities of this matter are
 ‘ projected into the air, like water thrown up
 ‘ by many jets-d’eaux. These projections pro-
 ‘ duce the appearance of burning sheafs of
 ‘ wheat, which rise to the height of thirty or
 ‘ forty feet, and fall back in various curves,

partly into their own basin, and partly the second, which is covered with a black matter. It is the reflected light of these burning jets which is seen from Naples during the night. The noise they make in their elevation and fall seems to be composed of that of fire-works, and the noise produced by the waves of the sea, when violently dashed against a rock.

The boilings and jets produce a perpetual evacuation of this matter. Through the aperture of four feet, at the base of the small mount, a burning rivulet of the same dimensions with the aperture continually flows, and descends in an inclined canal, and with a mean movement, into the second basin; where, after dividing into several rills, it stops and is extinguished.

This burning rivulet consists of fresh lava, which runs only eight days. But, if it continues to augment, it will in time produce a new overflowing into the plain, similar to that which happened two years ago. The whole is accompanied with a thick smoke, which has not the odour of sulphur, but precisely that which proceeds from a furnace where tiles are roasted.

We may, without danger, go round the margin of the crater; because the little hollow mount, from which the burning projections are made, is sufficiently distant to prevent all apprehensions.

'apprehensions. We may also, without danger, descend into the first basin; we may even go upon the margin of the second, if the reverberation of the burning matter does not prevent us.

'This was the real state of Vesuvius on the 15th of July 1753. But it perpetually changes its form and aspect. It now throws out no stones, and we perceive no flame*.'

These observations seem to prove, that the seat of the burning in this volcano, and perhaps in all others, is at no great depth in the bowels of the mountain, and that it is not necessary to suppose their fires on a level with, or lower than the sea, and to make their explosions from thence during the time of eruptions. It is sufficient that there are caverns and perpendicular fissures below, or rather at the side of the fire, which serve as ventilators to the furnace of the volcano.

M. de la Condamine, who has had more opportunities than any other philosopher, of examining a number of volcano's in the Cordelieres, has likewise explored that of Vesuvius, and all the adjacent territories.

'In the month of June 1755,' he remarks, 'the summit of Vesuvius formed an open funnel in a mass of ashes, calcarious stones, and
M 2 'sulphur,

* Note sent to M. de Buffon from Naples in September 1753.

‘ sulphur, which burned at different distances,
 ‘ and tinged the surface with its colour. The
 ‘ fire streamed through different crevices, in
 ‘ which the heat was so great, that, in a short
 ‘ time, it inflamed a stick thrust some feet down
 ‘ these fissures.

‘ For several years past, the eruptions of this vol-
 ‘ cano have been frequent; and, every time flames
 ‘ and liquid matter were thrown out, the moun-
 ‘ tain underwent considerable changes both in
 ‘ its height and external figure. . . . In a small
 ‘ plain, on the side of the mountain composed
 ‘ of ashes and stones projected from the volca-
 ‘ no, there is a breast of steep semicircular rocks
 ‘ of two hundred feet high, which bound this
 ‘ plain on the north. We perceived, near the
 ‘ crevices recently opened in the flanks of the
 ‘ mountain, the places through which the tor-
 ‘ rents of lava, with which the whole of this
 ‘ valley is filled, had issued during the last e-
 ‘ ruption.

‘ This spectacle presents the appearance of me-
 ‘ tallic waves cooled and congealed. We may
 ‘ form an imperfect idea of it by imagining a
 ‘ sea of thick and tenacious matter, the waves of
 ‘ which had begun to calm. This sea has its
 ‘ islands: They are detached masses, like hol-
 ‘ low spongy rocks, whimsically interspersed
 ‘ with vaults and grotto’s, under which the
 ‘ burning liquid had made a kind of reservoirs
 ‘ resembling

resembling furnaces. From these grotto's, with their vaults and pillars, hang numbers of scoriae in the form of irregular grapes of all shades and colours. . . .

All the mountains and coasts in the environs of Naples, are nothing but masses of burnt matter thrown out by volcano's which now no longer exist, and whose eruptions, which have been anterior to all history, probably formed the ports of Naples and Puzzoli. The same matters are conspicuous on the whole road from Naples to Rome, and even at the port of Rome itself.

The whole interior part of Mount Frascati, the chain of hills which extends from this place to Grotta-ferrata, Castlegandolfo, and as far as lake Albano, a great part of Mounts Tivoli, Caprarola, Viterbe, &c are composed of calcined stones, of pure ashes, of scoriae, of matter similar to the dross of iron and burnt earth, and of real lava; lastly, the whole matters resemble those of which the soil of Portici is composed, and which have issued from the sides of Vesuvius in so many different forms. . . . Hence we must necessarily conclude, that all this part of Italy has been overturned by volcano's. . . .

Lake Albano, whose margins are interpersed with calcined matters, is nothing but the mouth of an ancient volcano. . . . The chain of Ita-

'lian volcano's extends as far as Sicily; and
 'still exhibits a number of fires under different
 'forms; in Tuscany, we have the exhalations of
 'Firenzuola, and the warm waters of Pisa; in
 'the Ecclesiastic state, those of Viterbe, of
 'Norcia, of Nocera, &c.; in the kingdom of
 'Naples, those of Ischia, Solfatara, and Vesu-
 'vius; in Sicily and the islands adjacent to Æt-
 'na, the volcano's of Lipari, Stromboli, &c.
 'The other volcano's of this chain have been
 'extinct from time immemorial, and have left
 'such relicks as, though they do not always
 'strike us at first sight, fail not to be recognisa-
 'ble on an attentive examination *.

'It is very probable, says M. l'Abbé Mecati,
 'that, in past ages, the kingdom of Naples, be-
 'sides Vesuvius, was infested with several other
 'volcano's.

'Mount Vesuvius,' le P. de la Torré remarks,
 'seems to be a portion detached from that chain
 'of mountains which, under the name of *A-*
 '*pennines*, divides all Italy through its whole
 'length. . . . This volcano is composed of
 'three different mountains, one of them is Ve-
 'suvius properly so called; the other two are
 'Mounts Somma and Otajano. The two last
 'are situated toward the west, and form a kind
 'of

* Voyage en Italie, par M. de la Condamine; Acad. des
 Sciences, année 1757, p. 371.—379.

of semicircle round Vesuvius, with which they have a common base.

This mountain was formerly surrounded with fertile fields, and itself covered with trees and verdure, except the summit, which was flat and sterile, and where several open caverns were to be seen. The top was surrounded with rocks, which rendered it of difficult access. These rocks were so high, that they concealed the valley between Vesuvius and Mounts Somma and Otajano. The summit of Vesuvius, which has since sunk considerably, being then much more remarkable, it is not surprising that the ancients believed it had only one top.

The breadth of the valley is 2220 Paris feet, and its length nearly the same. It invests one half of Vesuvius, and, like all the sides of the mountain, it is covered with burnt sand and small pumice stones. The rocks on Mounts Somma and Otajano exhibit a few herbs, and the surface of these mountains is covered with trees and verdure. These rocks, at first sight, have the appearance of burnt stones; but, on a closer examination, they are, like the rocks of other mountains, composed of strata of natural stones, of a chefnut coloured earth, of chalk, and of white stones, which have not the smallest appearance of having been liquified by fire. . . .

Round

‘ Round Vesuvius we see openings which
 ‘ have been made at different times, and through
 ‘ which lavas had issued. These torrents of burn-
 ‘ ing matter, which sometimes come from the
 ‘ sides, and sometimes from the top of the
 ‘ mountain, descend into the plains, and some-
 ‘ times run as far as the sea, and harden like a
 ‘ stone when the matter cools. . . .

‘ On the summit of Vesuvius there is only a
 ‘ small margin of four or five palms wide, and
 ‘ describes a circumference of 5624 Paris feet.
 ‘ Upon this margin we can walk pretty commo-
 ‘ diously. The whole of it is covered with
 ‘ burnt sand, under which we find stones part-
 ‘ ly natural and partly calcined. . . . In
 ‘ two elevations on this margin, we find beds
 ‘ of natural stones, arranged in the same man-
 ‘ ner as in other mountains; which confutes
 ‘ the notion of those who regard Vesuvius as a
 ‘ mountain gradually raised above the plain of
 ‘ the valley. . . .

‘ The depth of the gulf where the matter
 ‘ boils is about 543 feet; and the height of the
 ‘ mountain above the level of the sea is 1677
 ‘ feet, which is one third of an Italian mile.

‘ This height has been more considerable.
 ‘ The eruptions which have changed the ex-
 ‘ ternal form of the mountain, have likewise
 ‘ diminished its elevation; for the parts they
 ‘ detached

* detached from the summit rolled into the 'gulf *.'

From all these examples, if we consider the external figure of Sicily and other countries ravaged by fire, we shall evidently perceive that no volcano exists which is purely isolated or detached. The surface of these countries every where presents a succession and sometimes groups of volcano's. This we have already seen with regard to *Ætna*, and shall give a second example of it in *Hecla*. A great part of the island, like Sicily, is only a group of volcano's, which I shall prove by the following observations.

The whole island ought be regarded as a vast mountain interspersed with deep cavities, concealing in its bowels great quantities of minerals, vitrified and bituminous substances, and rising from the midst of the sea in the form of a short flattened cone. Its surface presents to the eye nothing but tops of mountains covered with snow and ice; and lower down we have the picture of confusion and ruin. It is an enormous mass of stones and fragments of rocks, which are sometimes porous and half calcined, and exhibit a hideous appearance by their blackness and the marks of fire impressed upon them. The fissures and hollows of rocks are filled with a red, and sometimes with a black

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* Hist. du Mont Vesuve, par le P. de la Torr ; *Journal  tranger*, Janvier 1756, p. 182.—208.

or white sand: But, in the valleys between the mountains, we find agreeable plains*.

Most of Jokuts, which are mountains of a middle height, and overtopped by others of a greater elevation, are volcano's that occasionally throw out flames, and produce earthquakes: Of these there are no less than twenty in this island. The inhabitants in the neighbourhood of these mountains have learned by experience and observation, that, when the ice and snow rise to a considerable height, and stop the mouths of these cavities, which formerly discharged flames, that earthquakes are about to happen, which are always succeeded by eruptions of fire. It is for this reason that the Icelanders are at present afraid lest the Jokuts, which, in the year 1728, threw out flames in the canton of Skaftfield, should soon be again inflamed; the ice and snow being accumulated on their summits, and appearing to obstruct those vents which favoured the exhalations of the subterraneous fires.

In 1721, the Jokut called Koëtlegan, about five or six leagues to the west of the sea, near the bay of Portland, broke out into flames, after several succussions of the earth. This conflagration melted masses of ice of an enormous thickness, and gave rise to impetuous torrents, which deluged the country, and carried down

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* Introd. a l'Hist. du Denemarck.

to the sea prodigious quantities of earth, sand, and stones. The solid masses of ice, and the immense quantity of earth, stones, and sand, transported by the inundation, so loaded the sea, that, at half a mile from the coast, a small mountain was formed, which still appeared above the sea in the year 1750. We may form some idea of the quantity of matter carried down to the sea by this inundation, when we consider that it was obliged to retreat twelve miles beyond its former limits.

The inundation continued three days; and it was not till after this period that a person could pass on foot to the mountains.

Hecla, which has always been regarded as one of the most famous volcano's in the universe, on account of its tremendous eruptions, is now one of the least dangerous in the island. Mounts Koëtlegan and Krafle have recently made as great ravages as Hecla did of old. It has been remarked, that this last volcano has thrown out flames ten times only in the space of eight hundred years, namely, in the years 1104, 1157, 1222, 1300, 1341, 1362, 1389, 1558, 1636, and, lastly, in the year 1693. This eruption commenced on the 13th of February, and continued to the month of August following. All the other eruptions lasted a few months only. From the above dates it appears, that Hecla made its greatest ravages in

in the fourteenth century, having undergone no less than four eruptions ; that it remained perfectly tranquil during the 15th century ; and that it threw out no fire for one hundred and sixty years. From this period, there was one eruption only in the sixteenth, and two in the seventeenth century. We now perceive in this volcano neither fire, nor smoke, nor exhalations of any kind. We only find, in some small hollows, as is common in many other parts of the island, boiling water, stones, sand, and ashes.

In 1726, after a few succussions of the earth, which were felt only in the northern cantons, Mount Krafle began to throw out, with a dreadful noise, smoke, flames, ashes and stones. This eruption continued two or three years, without doing any damage ; because the whole rejected matter fell back upon the mountain, or round its base.

In 1728, the fire communicated with some mountains situated near Krafle, which burnt during several weeks. When the minerals they contained were melted, a river of fire ran gently toward the south into the country below these mountains. This river threw itself into a lake about three leagues from Mount Krafle, and, by the shock of the water, produced a horrible noise, and clouds of vapours. The running of the lava did not cease till 1729, when the mat-

ter

ter which formed it was probably exhausted. The lake was filled with an immense quantity of calcined stones, which raised its water considerably. It is about twenty leagues in circumference, and situated at an equal distance from the sea. We shall not take notice of the other volcano's in this island; it is sufficient that we have mentioned the most considerable of them*.

From this description we perceive, that the Jokuts of Hecla greatly resemble the secondary volcano's of *Ætna*; that, in both, the highest summit is tranquil; that the summit of *Vesuvius* is much sunk; and that probably those of *Ætna* and *Hecla* were formerly higher than they are at present.

Though the topography of volcano's in other parts of the world is not so well known as that of those in Europe, we may, nevertheless, presume, from analogy, and the similarity of their effects, that they resemble each other in every respect. They are all situated in islands, or upon the coasts of continents. Almost the whole of them are surrounded with secondary volcano's. Some of them are active, and others extinguished or quiet. The number of the latter is greater, even in the *Cordelieres*, which appear to be the most ancient domain of volcano's. In the south of Asia, the islands of *Sonde*, the *Moluccas*, and *Philippines*, bear evident marks of destruction.

* *Hist. Gen. des Voyages*, tom. 18. p. 9. 10. 11.

destruction by fire, and are still infested with volcano's. They are likewise very frequent in the island of Japan: This country is also more subject to earthquakes than any other part of the globe. In many places of Japan there are hot fountains. Most of the Indian islands, and all the seas of these eastern regions, present to our eyes nothing but peaks and detached summits, which vomit out fire, and deep indented coasts, the relicks of ancient continents which are now no more. Here the mariner often meets with ports which daily sink; and even whole islands have been known to disappear, and to be swallowed up, with their volcano's, by the waters. The seas in China are warm, which is a proof that there is a great effervescence in the maritime basins of this region. The hurricanes are tremendous, and water-spouts are frequent. The tempests are always preceded by general and perceptible boilings of the waters, and by various meteors and other exhalations with which the atmosphere is loaded.

The volcano of Teneriff has been explored by Dr Thomas Heberden, who resided several years in the village of Oratava, which is situated at the foot of the Peak. In his way he found large stones disposed on all sides at several leagues from the top of the mountain. Some of them appeared to be entire, and others seemed

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to have been burnt, and thrown to this distance by the volcano. In ascending the mountain he still saw burnt rocks scattered about in large masses.

'We arrived,' Dr Heberden remarks, 'at the famous grotto of Zegds, which is surrounded on all sides with enormous masses of burnt rocks. . . .

'A quarter of a league higher, we met with a sandy plain, in the middle of which there is a pyramid of sand, or yellowish ashes, called the *Sugar Loaf*. Round its base, fuliginous vapours perpetually arise. From thence to the summit, the distance might be half a quarter of a league. But the ascent is too difficult, on account of its steepness and the bad footing. . .

'However, we reached what is called the *Cauldron* which is twelve or fifteen feet deep. Its sides taper to the bottom, and form a cavity which resembles a reversed cone. . . . Here the ground is very warm; and, from about twenty tubes or chimneys, a thick sulphureous vapour arises. The whole ground seems to be mixed with sulphur, which gives the surface a brilliant appearance. . . .

'Upon almost all the stones in the neighbourhood, we perceive a greenish colour, intermixed with yellow like gold. A small part of this sugar-loaf is as white as chalk; and another

‘ other part, still lower, resembles red clay covered with salt. . . .

‘ In the middle of another rock, we discovered a hole, which exceeded not two inches in diameter, from whence proceeded a noise similar to that of a considerable quantity of water boiling over a great fire *.’

The Azores, the Canaries, the islands of Cape Verd, Ascension island, and the Antilles, which appear to be the relicks of ancient continents that united the Old Continent with America, offer nothing to our observation but burnt lands, or lands which still continue to burn. The volcano’s formerly sunk under the waters with the countries which supported them, excite such terrible tempests, that, in one of these storms which happened at the Azores, the suet fixed to the end of the plumb-line melted by the heat at the bottom of the sea.

III.

Of extinguished Volcano’s.

THE number of extinguished volcano’s exceed incomparably that of those which are active. They

* Observations on the Peak of Teneriff by Dr Heberden.

They are very numerous in almost every part of the earth. I might mention those remarked by M. de la Condamine in the Cordelieres, and by M. Frenaye in St Domingo *, near Port-au-Prince, and those of Japan and the other eastern and southern islands of Asia, the whole of which countries have been formerly ravaged by fire. But I shall limit myself to the extinguished volcano's of the isles of France and Bourbon, which have been recognised by some enlightened voyagers.

'The soil of the isle of France,' says M. l'Abbé de la Caille, 'is covered with a prodigious number of stones of all sizes, which are of a blackish ash-colour. Many of them are full of holes, like a sieve. Most of them contain a great quantity of iron; and the surface of the earth is covered with the ore of this metal. We likewise find, especially on the north coast of the island, a great many pumice stones, lavas, or refuse of iron, profound grottos, and other manifest vestiges of extinguished volcano's. . .

'The isle of Bourbon,' continues M. l'Abbé de la Caille, 'though larger than the isle of France, is only a large mountain, split as it were from its summit into three different parts. Its top is covered with wood, and inhabited; and two thirds of its declivity, which extends as far as

VOL. IX.

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* Note communicated to M. de Buffon, by M. Frenaye, March 10. 1777.

‘ the sea, are cleared and cultivated. The rest
 ‘ is covered with the lavas of a volcano, which
 ‘ burns slowly, and without any noise. It seems
 ‘ not to burn much, except during the rainy
 ‘ seasons.

‘ Ascension island has visibly been formed
 ‘ and burnt by a volcano. It is covered with
 ‘ a red earth, similar to brick-duft or burnt
 ‘ clay. The island is composed of several
 ‘ mountains from 100 to 150 fathoms high.
 ‘ There is one still larger to the south of the
 ‘ island, which is about 400 fathoms in height. .
 ‘ Its summit is double and lengthened : But all
 ‘ the others are pretty perfect cones, and cover-
 ‘ ed with red earth. The land and part of the
 ‘ mountains are interspersed with prodigious
 ‘ quantities of rocks full of holes, like sieves, and
 ‘ with very light calcarious stones, a number of
 ‘ which resembled coagulated milk ; some of
 ‘ them were laid over with a dirty white varnish
 ‘ approaching to green. Pumice stones are like-
 ‘ wise very frequent †.

The celebrated Captain Cook remarks, that,
 in an excursion to the interior parts of Otaheite,
 they found burnt rocks, like those of Madeira ;
 that all the stones bore incontestible marks of fire ;
 that they likewise perceived traces of fire in the
 clay upon the hills ; and that Otaheite and a
 number

† Mem. de l'Acad. des Sciences, année 1754, p. 111. 121.
 and 126.

number of adjacent islands might be supposed to be the relicks of a continent which had been swallowed by the explosions of subterraneous fire†. Philip Carteret tells us, that one of the Charlotte islands, situated in the $11^{\circ} 10'$ of south latitude, is of a prodigious height and a conical figure; that its summit is like a funnel, from which smoke issues, but no flames; and that, on the most southern coast of New Britain, there are three mountains, from one of which proceeds a large column of smoke‡.

We find basalts in the isle of Bourbon, where the volcano, though feeble, still acts; in the isle of France, where all the fires are extinct; and in Madagascar, where there are both active and extinguished volcano's. But, to mention no other basalts but those of Europe, we know that there are considerable masses of them in Ireland, in Britain, in Auvergne, upon the borders of the Elbe, in Misnia upon Mount Cattener, at Marienburg, at Weilbourg in the county of Nassau, at Lauterback, at Billstein, in several parts of Hesse, in Luface, in Bohemia, &c. These basalts are most beautiful lavas produced in all these countries, by volcano's which are now extinct. But we shall content ourselves with abridged descriptions of extinguished volcano's in France.

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† Cook's voyage, tom. 2. p. 431.

‡ Carteret's voyage, p. 250. and 275.

‘The mountains of Auvergne,’ says M. Guettard, ‘which have formerly, in my estimation, been volcano’s are those of Volvic two leagues from Riom, of Puy-de-dôme near Clermont, and of Mount Or. The volcano of Volvic has formed, by its different lavas, strata lying upon each other, and composing enormous masses, in which quarries are dug, and furnish stones to several places at a distance. . . . It was at Moulins where I first discovered lava. . . and being at Volvic, I perceived that the mountain was almost entirely composed of matters which had been thrown out by the eruptions of volcano’s.

‘The figure of this mountain is conical, and its base consists of rocks of a grayish white granite, or of the colour of a pale rose. . . . The rest of the mountain is composed entirely of blackish or reddish pumice stones, heaped upon each other without order or connection. . . . About two thirds up the mountain, we meet with irregular rocks, bristled with mishapen points turned to all sides, and of an obscure red or dirty black. They are solid and hard, and have no holes, like the pumice stones. . . Before arriving at the summit, we find a hole of some fathoms wide, and of a conical figure, approaching to that of a funnel. . . . The part of the mountain to the north and east, appeared to be solely composed of pumice stones. . . . In
‘Volvic

' Volvic, the beds of stone follow the inclination
 ' of the mountain, and seem to be continued
 ' through it, and to communicate with those dis-
 ' covered by the ravines a little below the sum-
 ' mit. . . These stones are of an iron gray co-
 ' lour, and seem to have a white grain, which
 ' comes out on the surface like an efflorescence :
 ' Though spongy, and full of small irregular
 ' holes, they are hard.

' Mount-puy-de-dôme is nothing but a mass
 ' of matter which indicates the dreadful effects
 ' of the most violent fire. . . . In those places
 ' of the mountain which are not covered with
 ' plants and trees, we travel among pumice
 ' stones, pieces of lava, and a gravel or sand,
 ' formed by a kind of iron dross and small bits
 ' of pumice-stones mixed with ashes.

' These mountains exhibit several peaks, and
 ' all of them have cavities or funnels of greater
 ' or smaller dimensions. One of these peaks, the
 ' road which leads to it, and the whole space as
 ' far as Puy-de-dôme, are only vast heaps of
 ' pumice-stones. The same observation is ap-
 ' plicable to the other peaks, which are fifteen
 ' or sixteen in number, situated in the same line
 ' from south to north, and all of them furnish-
 ' ed with funnels.

' The top of the peak of Mount Or is a rock
 ' composed of a tender whitish ash-coloured
 ' stone, similar to that on the summits of all the

‘ mountains in this volcanic country : It is only a little lighter than that of Puy-de-dôme.

‘ If I found not on this mountain as many vestiges of a volcano as in the other two, it must be partly ascribed to this circumstance, that Mount Or is more covered, through its whole extent, with trees and shrubs, than Mounts Volvic and Puy-de-dôme. . . . However, the south-east part is entirely bare, and entirely composed of stones and rocks, which seem to have been exempted from the effects of the fire. . . .

‘ But the peak of Mount Or is a cone similar to those of Volvic and Puy-de-dôme. To the east of this point is the Peak du Capuchin, which is likewise conical, but not so regular as those of the preceding mountains. It even appears that this peak has undergone more changes in its structure; for every thing is more irregular, and broken into smaller portions. . . . There are still several other peaks, the bases of which rest upon the ridge of the mountain; but they are all overtopped by Mount Or, which is 509 fathoms high. . . . The peak of Mount Or is very rugged : It terminates in a point about fifteen or twenty feet in diameter. . . .

‘ There are several conical mountains between Thiers and Saint Chaumont, which led me to think,’ says M. Guettard, ‘ that they might have been burnt. . . . Though I have never
‘ been

‘ been at Pontgibault, I have sufficient proofs to
 ‘ convince me that the mountains of this canton
 ‘ are extinguished volcano’s ; I have received
 ‘ fragments of lava from them, which it was
 ‘ easy to recognise by the yellow and blackish
 ‘ points of vitrified matter, which are the most
 ‘ certain characteristics of volcanic produc-
 ‘ tions *.’

The same M. Guettard and M. Faujas have found, on the left bank of the Rhone, and a good way into the country, very large fragments of basaltic columns. . . . In ascending into the Vivarais, they found in a rapid brook a vast collection of volcanic matter, which they followed to its source. It was not difficult to recognise the volcano. It is a very high mountain, on the top of which they found a mouth of about 80 feet in diameter. Below this mouth the lava is partly visible. It has flowed down the ravines in great masses, for the space of seven or eight thousand fathoms. The matter has heaped together while yet burning in certain places ; and, after fixing, it chapped and split through its whole thickness, and left the whole plain covered with innumerable columns, from fifteen to thirty feet long by about seven inches in diameter †.

‘ Having

* Mem. de l’Acad. des Sciences, année 1752, p. 27.—58.

† Journal de Physiques, par M. l’Abbé Rozier ; *Mois de Decembre* 1775, p. 516.

‘ Having proceeded to Montferrier,’ says M. Montet, ‘ a village about a league distant from Montpellier. . . . I found a number of black stones, detached from each other, and of different figures and sizes. . . . I compared them with others which were unquestionably the production of volcano’s, . . . and found them to be of the same nature. Hence I no longer doubted that these stones of Montferrier were a very hard lava, or a matter melted by a volcano, which had long been extinguished. The whole mountain of Montferrier is interspersed with these stones, and the streets are paved and the village partly built with them. . . . The surfaces of these stones are, in general, full of holes or porosities, which sufficiently indicate that they have been formed of matter melted by a volcano. This lava is dispersed over all the grounds adjacent to Montferrier. . . .

‘ On the side of Pézenas, extinguished volcano’s are very numerous The whole country is full of them, especially from Cap d’Agde, which itself is an extinguished volcano, to the foot of that chain of mountains that commences five leagues to the north of this coast, and upon their declivity, or at a little distance from them, are situated the villages of Livran, Peret, Fontés, Néfiez, Gabian, and Faugères. In going from south to
‘ north,

' north, we find a remarkable plinth or chaplet,
' which begins at Cap d'Agde, and comprehends
' Mounts Saint-Thibery and Causse, (mountains
' situated in the middle of the plains of Bressan),
' the peak of Valros in the territory of this vil-
' lage, the peak of Montredon in the territory
' of Tourbes, and that of Saint-Marthe, near
' the royal Priory of Cassan. Besides, from the
' foot of the mountain, a great and long mass
' arises, and terminates to the south near the
' Grange of Prés, and from east to west between
' the village of Caus and that of Nizas. . . . It
' is to be remarked of this canton, that it con-
' sists of almost nothing but a mass of lava, and
' that in the middle of it there is a round mouth
' or distinct crater about 200 fathoms in diame-
' ter, which formed a pond that has since been
' drained by a deep cut through the hard lava,
' which is disposed into strata, or rather conti-
' guous undulations. . . .

' In all these places we find lava and pumice
' stones. Almost the whole village of Pezenas
' is paved with lava. The rock of Agde is no-
' thing but a hard lava, and the whole of this
' village is built and paved with this lava, which
' is very black. . . . Almost the whole territory
' of Gabian, in which is the famous fountain of
' Petroleum, is bestrewed with lava and pumice-
' stones.

' We likewise find at Causse, Bajan, and
' Saint-

‘ Saint-Thibery, a considerable quantity of basalts, which are commonly prisms with six sides, and from ten to fourteen feet in length. These basalts are found in a place where the vestiges of an ancient volcano are no longer recognisable.

‘ The baths of Balaruc every where present us with relicks of an extinguished volcano. The stones found there are nothing but pumices of different sizes. . . .

‘ In all the volcano’s I examined, I remarked, that the matter or stones thrown out are of various figures. Some of them are in large, heavy, and hard masses, like the rock of Agde: Others, like those of Montferrier and the lava of Tourbes, are in detached pieces of considerable weight and hardness*.’

M. Villet, of the academy of Marseilles, has transmitted to the king’s cabinet some specimens of lava and other matters found in the extinguished volcano’s of Provence; and he writes me, that, a league from Toulon, there are evident vestiges of an ancient volcano; and that, having descended a ravine to the foot of this old volcano of Mount d’Ollioules, he was struck with the appearance of a detached rock which had come down from the mountain. It was calcined; and, having broke off some pieces, he found

* Mem. de l’Acad. des Sciences, année 1760, p. 466.—
473.

found in the heart some sulphureous particles so strongly marked, that he no longer doubted the ancient existence of these volcano's which are now extinct*.

M. Valmont de Bomare has observed, in the territory of Cologne, the vestiges of several extinguished volcano's.

I could give many other examples, which all concur in proving, that the number of extinguished volcano's is perhaps a hundred times greater than that of those now actually existing. I must here remark, that, between these two, there are, as in all the other operations of Nature, intermediate states, degrees, and shades, of which we can only lay hold of the principal traits. For example, the Solfataras are neither active nor extinguished volcano's, but seem to participate of both. These no man has better described than one of our learned Academicians, M. Fougereux de Bondaroy; I shall, therefore, lay before the reader his chief observations.

' Solfatara, situated four miles west from Naples, and two miles from the sea, is surrounded on all sides with mountains. Before arriving at it, we must ascend about half an hour. The space comprised between the mountains forms a basin of about 1200 feet in length by 800 feet broad. With regard to the mountains,

* Lettre de M. Villet a M. de Buffon; *Marseille*, le 8. Mai 1775.

‘ tains, it lies in a bottom ; but it is not so low
‘ as the ground you traverse in going to it.
‘ The soil in the bottom of the basin is a very
‘ fine, close, beaten sand, and it is so dry and
‘ parched that it produces no vegetables. The
‘ colour of the sand is yellowish. . . . The sul-
‘ phur, which is found in great quantities among
‘ the sand, gives it this colour. The mountains
‘ which bound the greatest part of the basin
‘ consist of bare rocks, without earth or plants.
‘ Some of them are split, and their parts are
‘ burnt and calcined; but the whole present no
‘ arrangement or order in their position. . . .
‘ They are covered with greater or smaller quan-
‘ tities of sulphur, which is sublimed in this part
‘ of the mountain and in the neighbouring basin.

‘ The opposite side consists of a better soil. . .
‘ Neither does it present furnaces similar to those
‘ formerly mentioned, and which are common
‘ on the other side.

‘ In several places, we find, in the bottom of
‘ the basin, apertures or mouths, from which
‘ issues smoke, accompanied with a heat that
‘ would burn the hands smartly; but it is not
‘ strong enough to kindle paper. . . .

‘ The adjacent places produce a heat which
‘ is felt through the shoes, and a disagreeable
‘ odour of sulphur exhales from them. . . When
‘ a sharp pointed stick is thrust into the ground,
‘ there

‘ there soon issues a vapour or smoke, similar to
‘ that which exhales from the natural crevices.

‘ Through these apertures, a small quantity
‘ of sulphur is sublimed, together with a salt
‘ which has all the characters of sal ammoniac.

‘ On several stones which surround Solfatara,
‘ we find threads of allum. . . . Lastly, sulphur
‘ is collected from Solfatara. . . . This substance
‘ is extracted from grayish stones, interspersed
‘ with shining particles, which are sulphur cry-
‘ stallized between the stony particles. . . These
‘ stones are sometimes impregnated with allum.

‘ By striking the middle of the basin with
‘ our foot, we easily perceive that the ground is
‘ hollow below.

‘ If we traverse the side of the mountain,
‘ where the mines are most numerous, we find
‘ lavas, pumice-stones, the dross of volcano's,
‘ &c. In a word, the whole appearances, when
‘ compared with the matters at present furnish-
‘ ed by Vesuvius, demonstrate that Solfatara was
‘ formerly the mouth of a volcano. . . .

‘ The basin of Solfatara has often changed
‘ its form ; and we may conjecture that it will
‘ still assume others. This territory daily hol-
‘ lows and undermines itself. It at present
‘ forms a vault which covers an abyfs. . . . If
‘ this vault sinks, the abyfs will probably fill
‘ with water and produce a lake*.’

M.

* Mem. de l'Acad. des Sciences, année 1765, p. 267.—283.

M. Fougereux de Bonderoy has likewise made some observations on Solfataras in other parts of Italy.

‘I have been,’ says he, ‘at the source of a rivulet, which we pass in the road between Rome and Tivoli, the water of which has a strong odour of liver of sulphur. . . . It forms two small lakes, about forty fathoms in their greatest extent. . . .’

‘One of these lakes, according to the plumb-line we were obliged to use, was, in different places, 60, 70, and 80 fathoms deep. . . . In these lakes we saw several floating islands, which sometimes change their situation. . . . They are composed of plants reduced into a kind of light turf, upon which the waters, though corrosive, have no effect. . . .’

‘The heat of these waters was 20 degrees, when the thermometer in the open air stood at 18 degrees. Thus it appears from experiment, that the heat of these waters is inconsiderable. . . . They exhale a disagreeable odour; and this vapour changes the colour of vegetables and of copper *.’

‘The Solfatara of Viterbe,’ M. l’Abbé Mazzeas remarks, ‘has a mouth of from three to four feet only. Its waters boil, exhale an odour of the liver of sulphur, and petrify their canals, like those of Tivoli. . . . The de-
gree

* Mem. de l’Acad. des Sciences, année 1770, p. 1.—7

'gree of their heat is that of boiling water,
'and sometimes more. . . The volumes of
'smoke, which sometimes arise, indicate a still
'greater heat; and yet the bottom of the basin
'is covered with plants which grow in the
'bottom of the lakes, and in the marshes.
'In ferruginous soils, these waters produce vi-
'triol,' &c. †.

'In several of the Apennine mountains, and
'particularly in those on the road from Bologna
'to Florence, we find fires, or vapours which re-
'quire only the approach of a candle to inflame
'them. . . .

'The fires of Mount Cenida, near Pietramala,
'are situated at different heights of the moun-
'tain, upon which we find four mouths that
'throw out flames. . . . One of these fires is
'in a circular place surrounded with a rising
'ground. . . . Here the earth appears to be
'burnt, and the stones are blacker than those
'in the neighbourhood; there likewise issues,
'here and there, a lively, blue, clear flame,
'which rises from three to four feet high. . . .
'But, beyond this circular space, we see no fire,
'though the heat of the ground is perceptible
'at the distance of sixty feet from the centre
'of these flames. . . .

'Along a fissure or crevice in the neighbour-
'hood of the fire, we hear a dull noise, like that of
'wind

† Mem. des Savans étrangers, tom. 5. p. 325.

' wind moving through a subterraneous passage.
 ' Near this place, we find two sources of hot
 ' water. . . The ground, in which fire has long
 ' existed, is neither depressed nor elevated. . .
 ' Near this fire we see no volcanic stones, nor
 ' any mark which indicates that fire has ever
 ' been thrown out. However, some little hills
 ' in the neighbourhood have every appearance
 ' of having been formed, or at least changed
 ' by volcano's. . . . In 1767, succussions of an
 ' earthquake were felt in the environs; but
 ' no change was produced on the fire, neither
 ' was the smoke increased or diminished. . . .

' About ten leagues from Modena, at a
 ' place called *Barigazzo*, there are five or six
 ' openings where, at particular times, flames ap-
 ' pear, which are extinguished by a strong
 ' wind: There are likewise vapours which in-
 ' flame by contact with fire. . . . But, notwith-
 ' standing the unequivocal vestiges of extin-
 ' guished volcano's which subsist in most of these
 ' mountains, the fires seen there are not new
 ' volcano's forming, because they never throw
 ' out any volcanic matter *.'

Hot waters, as well as the fountains of Pe-
 troleum, and other bituminous and oily substan-
 ces, should be regarded as another shade be-
 tween extinguished and active volcano's.

When

* Mem. sur le Pétrole, par M. Fougeroux de Banderoy,
 dans ceux de l'Acad. des sciences, année 1770, p. 45.

When subterraneous fires exist near strata of coal, they dissolve the coal, and give rise to most sources of bitumen : They likewise occasion the heat of the hot springs which run in their neighbourhood. But these subterraneous fires now burn with tranquility ; and we only recognise their ancient explosions by the substances they have formerly rejected. They ceased to act when the sea retired from them ; and, as already remarked, I believe there is no longer any reason to dread the return of these direful explosions, since every observation concurs in showing that the sea will always retire farther and farther.

IV.

Of Lavas and Basalts.

To what we have said on the subject of volcano's, we shall add some remarks on the motion of lavas, and on the time necessary for their cooling and their conversion into vegetable soil.

The lava which runs from the foot of the eminences formed by the matters rejected by the volcano, is an impure glass in fusion. It is a tenacious, viscous, and half fluid substance.

Hence the torrents of this vitrified matter, when compared to torrents of water, run slowly ; and yet they often proceed to great distances. In these torrents of fire, however, there is another movement than what takes places in those of water : This movement tends to elevate the whole running mass, and is produced by the expansive force of the heat in the interior parts of the burning torrent. The external surface cools first ; the liquid fire continues to run below ; and, as heat acts equally on all sides, the fire, which endeavours to escape, elevates the superior parts that are already consolidated, and often forces them to rise perpendicularly. This is the origin of those large masses of lava in the form of rocks, which are found in the course of almost every torrent where the declivity is not great. By the efforts of this internal heat, the lava makes frequent explosions ; its surface opens, and the liquid matter springs up and forms those masses which we see elevated above the level of the torrent. Le P. de la Torr , I believe, is the first person who observed this internal movement of burning lavas, which is always more violent in proportion to their thickness and the gentleness of the declivity. This effect is common to all matters liquified by fire, and every man may see examples of it in our common founderies *.

If

* The lava of iron founderies exhibits the same effects. When this vitreous matter runs slowly, and accumulates at the

If we observe those large ingots or masses of melted iron, which run in a mould or canal with a very small declivity, we shall perceive that they have a tendency to rise like arches, especially when the stream is very thick *. We have formerly shewn, by experiments, that the time of consolidation is always proportioned to the thickness of the ingots, and that, when their surfaces are hardened, the interior parts still continue to be liquid. It is this internal heat which elevates the ingots and makes them blister. If their thickness were greater, there would be produced, as in the torrents of lava, explosions, rup-

O 2

tures

the base, we see eminences arise, which are bubbles or concave hemispheres of glass. These bubbles increase, when the expansive force is great, and the matter has little fluidity: It then suddenly explodes into a flame, and makes a considerable report. When the liquified matter is sufficiently adhesive to suffer a great dilatation, these superficial bubbles acquire a volume of eight or ten inches in diameter, without breaking. When the vitrification is less complete; and the matter is viscous and tenaceous, the bubbles are smaller, and in cooling form concave eminences called *toad's eyes*. What happens in miniature in our founderies, is likewise exhibited upon a larger scale in the lavas of volcano's.

* I have not mentioned some particular causes which frequently produce a curvature or swelling in our melted ingots: For example, when the matter is not very fluid, or when the mould is too moist, the ingots bend considerably; because these causes concur in augmenting the effect of the first. Thus the humidity of the ground, on which the torrents of lava descend, and the internal heat concur in raising the mass, and in producing explosions, which are always accompanied with those jets of matter formerly mentioned.

tures in the surface, and perpendicular jets of metallic mater pushed out by the action of the fire inclosed in the interior parts of the ingots. This explication, drawn from the nature of the thing itself, leaves no doubt concerning the origin of those eminences so frequent in valleys and plains, which have been over-run or covered with lava.

When, after descending from the mountain and traversing the fields, the burning lava arrives at the margin of the sea, its course is suddenly interrupted, the torrent advances, and, like a powerful enemy, makes the water at first retire: But the water by its immensity, by the resistance of its cold, and by its power of arresting and extinguishing fire, soon consolidates the torrent of burning matter, which can now proceed no farther, but rises up, accumulates new strata, and forms a perpendicular wall, from the top of which the lava falls and applies itself to the face of the wall thus formed. It is this falling and arresting of the burning matter that gives rise to basaltic prisms* and their jointed columns. These prisms have generally five, six, or seven sides, sometimes only three or four, and

* I shall not here inquire into the origin of the term *basalt*, which M. Desmarets of the academy of Sciences, a learned naturalist, believes to have been applied by the ancients to different kinds of stones; but shall limit myself to the *basaltic lava*, which appears under the form of prismatic columns.

and sometimes eight or nine. The basaltic columns are formed by the perpendicular fall of the lava into the sea, whether it falls from high rocks on the shore, or from a wall raised by its own accumulations. In both cases, the cold and humidity of the water arrest the burning matter, and consolidate its surfaces the moment it falls; and the successive bundles or masses of lava apply themselves to each other. As the internal heat of these masses tends to dilate them, a reciprocal resistance is created; and the same effect is produced as happens in the swelling of pease, or rather of cylindrical grain, when squeezed in a close vessel filled with boiling water. Each of these grains would assume a hexagonal figure by reciprocal compression. In the same manner, each bundle or mass of lava assumes several sides by dilatation and reciprocal resistance; and, when the resistance of the surrounding bundles is stronger than the dilatation of the bundle surrounded, instead of becoming hexagonal, it has only three, four, or five sides. But, if the dilatation of the surrounded bundle is stronger than the resistance of the surrounding bundles, it assumes seven, eight, or nine sides, which are always longitudinal.

The transverse articulations of these prismatic columns are produced by a cause still more simple: The bundles of lava fall not in a regular and continued stream, nor in equal masses.

Hence, if there are intervals in the fall of the matter, the superior surface of the forming column being partly consolidated, is hollowed by the weight of the succeeding mass, which then moulds itself into a convex form in the concavity or depression of the first. This is the productive cause of those joints or articulations which appear in the greater part of prismatic columns. But, when the lava falls in an uninterrupted stream, then the basaltic column is one continued mass, without any articulations. In the same manner, when, by an explosion, some detached masses are darted from the torrent of lava, these masses assume a globular or elliptical figure, and are even sometimes twisted like cables. To this simple explication, all the forms of basalts and figured lavas may be easily referred.

It is to the rencounter of lava with the waves, and its sudden consolidation, that the origin of these bold coasts, which border all the seas at the foot of volcanic mountains, is to be ascribed. The ancient ramparts of basalt found in the interior parts of continents, shew that the sea has been in the neighbourhood of these volcanoes when they had thrown out lava. This is an additional proof of the ancient abode of the waters upon all the lands now inhabited.

The torrents of lava are from a hundred to two and three thousand fathoms broad, and sometimes one hundred and fifty, and even two hundred

hundred feet thick! And, as we have found by experience, that the time of the cooling of glass is to that of the cooling of iron as 132 to 236, and that the times of their respective consolidation are nearly in the same proportion, it is easy to infer, that, to consolidate the thickness of ten feet of glass or lava, $201 \frac{1}{3}$ minutes would be necessary, since it requires 360 minutes to consolidate ten feet thick of iron, consequently it will require 4028 minutes, or 67 hours 8 minutes, to consolidate 200 feet thick of lava: By the same rule we shall find, that 30 days $\frac{1}{4}$, or a month, will be requisite before the surface of this lava of two hundred feet thick be sufficiently cold to admit of being touched. Hence a year will be necessary to cool a lava of two hundred feet thick, so as to admit of being touched, without burning, at the depth of one foot; and, at ten feet deep, it will be still so warm, at the end of ten years, as not to be tangible; and a hundred will be requisite to cool it to the same degree in the middle of its thickness. Mr Brydone relates, that, more than four years after the lava had flowed, in the year 1766, at the foot of *Ætna*, it was not perfectly cool. *Massa*, a Sicilian author worthy of credit, tells us, 'that, being at Catania, eight years after the great eruption in 1669, he found, that the lava in several places was not entirely cool *.'

About

* Voyage an Sicile, tom. 1. p. 213.

About the end of April 1771, Sir William Hamilton dropt pieces of dry wood into a crevice in the lava at Vesuvius, and they were instantly inflamed: The lava issued from the mountain on the 19th of October 1767, and had no communication with the fire of the volcano. The place where this experiment was made, was at least four miles distant from the mouth from which the lava issued. He is firmly persuaded, that many years are necessary to cool a lava of this thickness (about 200 feet).

I have had no opportunity of making experiments upon consolidation and cooling, but with balls of some inches in diameter. The only method of making experiments on a larger scale would be, to observe lavas, and to compare the times exhausted in their consolidation and cooling, according to their different thicknesses. I am satisfied that these observations would confirm the law I have established for the cooling of bodies from the state of fusion to the common temperature; and although these new observations are by no means necessary to support my theory, still they would help to fill up that immense gap between a cannon-ball and a planet.

It now remains for us to examine the nature of lava, and to show, that, in time, it is converted into fertile earth; which recalls the idea of the first conversion of the scoriae of the primitive

tive glass that covered the whole surface of the globe after its consolidation.

‘ Under the denomination of lava, we comprehend not,’ says M. de la Condamine, ‘ all the matter thrown out by a volcano, such as ashes, pumice-stones, gravel, and sand; but solely those reduced to a liquid state by the action of fire, and which, by cooling, form solid masses, whose hardness surpasses that of marble. This restriction notwithstanding, many other species of lava may be conceived, according to the different degrees of fusion in the mixture, the greater or smaller quantity of metal, and its greater or lesser intimate union with the various matters. Beside many intermediate kinds, three species are easily distinguishable. The purest lava resembles, when polished, a stone of an obscure dirty gray colour. It is smooth, hard, heavy, and interspersed with small particles similar to black marble, and whitish points. It seems to contain metallic particles. At first sight, it resembles serpentine, when the colour of the lava does not tend to green. It receives a pretty fine polish, which is more or less vivid in different parts. It is made into tables, chimney-pieces, &c.

‘ The coarsest kind of lava is rugged and uneven. It resembles the scoriae or dross of iron. The most common species holds a middle rank between the two extremes:

‘ It

‘ It is that which we every where find in large
 ‘ masses upon the sides of Vesuvius and in
 ‘ the adjacent fields, where it has run in torrents.
 ‘ In cooling, it has formed masses similar to
 ‘ ferruginous and rusty rocks, which are often
 ‘ many feet thick. These masses are frequent-
 ‘ ly interrupted and covered with ashes and
 ‘ calcined matter. . . . It is under several
 ‘ alternate strata of lava, ashes, and earth, the
 ‘ whole of which forms a crust of from 60
 ‘ to 80 feet thick, that temples, porticos, sta-
 ‘ tues, a theatre, and an entire city have been
 ‘ discovered *.

M. Fougereux de Bondaroy remarks, ‘ that,
 ‘ immediately after an eruption of burnt earth
 ‘ or of a kind of ashes, Vesuvius generally
 ‘ throws out lava, which runs down the fissures
 ‘ or furrows made in the mountain. . .

‘ The mineral matter inflamed, melted, and
 ‘ flowing, or lava properly so called, issues through
 ‘ cracks or crevices with more or less impetu-
 ‘ osity, and in greater or smaller quantity, accor-
 ‘ ding to the violence of the eruption. It spreads
 ‘ to a greater or smaller distance, according to
 ‘ the degree of fluidity, and the declivity of the
 ‘ mountain, which more or less retards its cool-
 ‘ ing. . .

‘ That which now covers a part of the land
 ‘ at

* Mem. de. l’Acad. des Sciences, année 1757, p. 374.

' at the foot of the mountain, and which some-
 ' times stretches as far as Portici, consists of
 ' large heavy masses, bristled with points on
 ' their upper surface. The surface which rests
 ' on the ground is flatter : As these pieces lie
 ' above each other, they have some resemblance
 ' to the waves of the sea. When the pieces are
 ' larger and more numerous, they assume the
 ' figure of rocks. . .

' In cooling, the lava affects various forms. .
 ' The most common is that of tables or boards
 ' of greater or smaller dimensions. Some pie-
 ' ces are six, seven, and eight feet long. It
 ' breaks into this form in cooling and consoli-
 ' dating. This is the species of lava which is
 ' bristled with points. . .

' The second species resembles great ropes :
 ' It is always found near the mouth of the
 ' volcano, and appears to have been suddenly
 ' fixed, and to have rolled before it hardened.
 ' It is lighter, more brittle, more bituminous,
 ' and softer, than the first species. By break-
 ' ing it, we likewise perceive that its substance
 ' is not so close and compact. . .

' At the top of the mountain, we find a third
 ' species of lava, which is brilliant, and com-
 ' posed of threads which sometimes cross one an-
 ' other. It is coarse, and of a reddish violet co-
 ' lour. . . . Some fragments are sono-
 ' rous, and have the figure of stalactites. . .

' Lastly,

‘ Lastly, in certain parts of the mountain, we
 ‘ find lavas of a spherical form, and appear to have
 ‘ been rolled. It is easy to conceive how the
 ‘ figures of these lavas might be varied by a
 ‘ number of accidental circumstances *,’ &c.

Matter of every kind enters the composition of lavas. Iron and a small quantity of copper have been extracted from the lava found on the summit of Vesuvius. Some specimens are so impregnated with metallic substances as to preserve the flexibility of metal. I have seen two large tables of lava of two inches thick, which were polished like marble, and bended with their own weight. I have seen others, which were bended by a weight, and resumed their horizontal position by their own elasticity.

All lavas, when reduced to powder, are, like glass, susceptible of being converted, by the intervention of water, first into clay, and afterwards, by the mixture of dust and corrupted vegetables, into excellent soil. These facts are apparent from the vast and beautiful forests which surround *Ætna*, and grow upon a bottom of lava covered with several feet of good earth: The ashes are more quickly converted into earth than the powder of glass or of lava. In the craters of old extinguished volcanoes, as well as on the ancient rivers of lava, we find very fertile soils. Hence the devastations occasioned by volcanoes are limited by
 time ;

* Mem. de l’acad. des Sciences, année 1766 p. 75.

time ; and, as Nature is always more disposed to produce than to destroy, she, in a few ages, repairs the devastations of fire, and restores to the earth its former fertility by the very same materials she had employed for the purposes of destruction.

ADDL

ADDITIONS to the Article, Of Caverns,
Vol. I. p. 442.

Of Caverns formed by the Primitive Fire.

IN my theory of the Earth, I mentioned only two kinds of caverns, the one produced by the fire of volcano's, and the other by the motion of subterraneous waters. Those two species of caverns are not situated at great depths. They are even new, when compared with those vast cavities, which were formed at the time the globe first assumed a solid form; for, at this period, all the superficial eminences and hollows, and all the cavities in the interior parts of the earth, especially near the surface, were produced. Several of those caverns produced by the primitive fire, after being supported for some time, have afterwards split by cooling, which diminishes the volume of every kind of matter; these would soon fall in, and, by their sinking, form basins or reservoirs for the sea, into which the waters, formerly much elevated above this level, ran, and abandoned the lands which they originally

nally covered. It is more than probable, that a certain number of these ancient caverns still subsist in the interior parts of the globe, and by their sinking may produce similar effects, and give rise to new receptacles to the waters. In this case, they will partly abandon the basin which they now occupy, and run, by their natural propensity, into these lower places. For example, we find beds of sea shells in the Pyrennees 1500 fathoms above the present level of the ocean. Hence it is certain, that the waters, when these shells were formed, rose 1500 fathoms higher than they do at present. But, when the caverns, which supported the lands that are now the bed of the Atlantic ocean, sunk, the waters which covered the Pyrennees and the whole of Europe would run with rapidity into these reservoirs, and, of course, leave uncovered all the lands in this part of the world. The same revolution would extend to every other country. The waters appear to have never reached the summits of the highest mountains; because they exhibit no relicks of marine productions, and no sufficient marks of a long abode of the waters. However, as some of the matters of which they are composed, though all of the vitrescent kind, seem to have derived their solidity and consistence from the intervention and cement of water, and as they appear to have been formed, as already remarked, in
the

the masses of sand, or glass dust, which formerly lay on the peaks of mountains, but which, in the progress of time, have been carried down to their bottoms by the rains, we cannot pronounce positively, that the waters of the sea never stood higher than the places where shells are now found: The waters have perhaps stood much higher, even before their temperature permitted the existence of shells. The greatest height reached by the universal ocean is to us unknown. But we know that the waters were elevated from 1500 or 2000 fathoms above their present level; since shells are found in the Pyrennees at 1500 hundred fathoms, and in the Cordelieres at 2000.

If all the peaks of mountains were formed of solid glass, or of other matters immediately produced by fire, it would be unnecessary to have recourse to the abode of the waters, or to any other cause, in order to conceive how they assumed their consistence. But most peaks of mountains seem to be composed of matters, which, though vitrifiable, have acquired their solidity by the intervention of water. We cannot, therefore, determine whether their consistence is solely owing to the primitive fire, or whether the intervention and cement of water were not requisite to complete the operation of fire, and to bestow on these vitrifiable masses the qualities which they possess. Besides, this supposition prevents

prevents not the primitive fire, which at first produced the greatest inequalities on the globe, from being the chief cause of those chains of mountains that traverse its surface, and particularly of their cores or nuclei; but the contours of these same mountains have perhaps been disposed and fashioned by the waters at a subsequent period; for it is upon these contours, and at certain heights, that shells and other productions of the sea are found.

To acquire a clear notion of the ancient caverns formed by the primitive fire, we must suppose the globe to be deprived of all its waters, and of all the matters which cover its surface, to the depth of ten or twelve hundred feet. By removing in idea this external bed of earth and water, the globe will present to us the form it possessed about the time of its first consolidation. The whole mass was composed of vitreous rock, or, if you will, of melted glass; and this matter, in cooling and acquiring consistence, produced, like all other melted bodies, eminences, depressions, and cavities, upon the whole surface of the globe. These internal cavities formed by fire, are the primitive caverns, and they are more numerous in the southern than in the northern regions; because the rotatory motion, which elevated the equatorial regions before consolidation, likewise produced the greatest derangement of the matter, and, by

VOL. IX. P retarding

retarding the consolidation, would concur with the action of the fire in giving rise to a greater number of inequalities in this than in any other part of the globe. The waters coming from the Poles could not approach those burning regions before they cooled. The vaults which supported these regions having successively fallen in, the surface sunk and broke in a thousand places. For this reason, the greatest inequalities of the globe are found in the equatorial regions: There the primitive caverns are more numerous than in any other part of the earth. They are likewise more profound, *i. e.* perhaps five or six leagues deep; because the matter of the globe, while in a liquid state, was agitated to that depth by the motion of rotation. But all the caverns in high mountains derive not their origin from the operation of primitive fire. Those alone which are deeply situated below the mountains can be ascribed to this cause. The more exterior and more elevated have been formed, as already remarked, by the operation of secondary causes. Hence the globe, deprived of its waters and the matters transported by them, would present to us a surface much more irregular than it appears with the aid of this covering. The great chains of mountains and their peaks and ridges, have not now the appearance of half of their real height. The whole are attached by their bases to a vitrifiable rock,

rock, and are of the same nature. Thus we should reckon three species of caverns produced by Nature: The first by the force of the primitive fire; the second by the action of water; and the third by that of subterraneous fires: Each of these caverns, though different in their origin, may be distinguished by examining the matters they contain, or by which they are surrounded.

P 2

A D D I

ADDITIONS to the Article, Of the effect of Rains, Marshes, Subterraneous Wood and Water, Vol. I. p. 473.

I.

Of the sinking and derangement of certain Lands.

THE rupture of caverns, and the action of subterraneous fires, are the chief causes of the great revolutions which happen in the earth; but they are often produced by smaller causes. The filtration of the water, by diluting the clay, upon which almost all calcarious mountains rest, has frequently made those mountains incline and tumble down. Of these remarkable events I shall subjoin some examples.

‘ In the year 1757,’ says M. Perronet, ‘ a part
 ‘ of the ground situated about half-way before
 ‘ we arrive at the Castle of Croix-fontaine, opened in many places, and successively tumbled down. The terrace wall, which inclosed
 ‘ this ground, was overturned, and the road,
 ‘ which was formerly at the foot of the wall,
 ‘ was obliged to be carried to a considerable distance.’

' stance. This ground rested upon a base ' of inclined earth.' This learned and chief engineer of our highways and bridges mentions another accident of the same kind which happened, in the year 1733, at Pardines, near Issoire in Auvergne. The ground, for about 400 fathoms in length by 300 in breadth, descended upon a pretty distant meadow, with all its houses, trees, and herbage. He adds, that considerable portions of ground are sometimes transported either by the rupture of reservoirs of water, or by the sudden melting of snows. In 1757, at the village of Guet, about ten leagues from Grenoble, on the road to Briançon, the whole ground, which lies on a declivity, split and descended in an instant towards Drac, which is about a mile distant. The earth split in the village, and the part which moved off was six, eight, and nine feet lower than its former station. This ground was situated on a pretty solid rock, which was inclined to the horizon about forty degrees*.

To these examples I shall add another fact, of which I have been a constant witness, and which has cost me a considerable expence. The detached rising ground, upon which the town and old castle of Montbard are situated, is elevated 140 feet above the level of the river, and its most rapid descent is to the north-east. This

P 3

rising

* Hist. de l'Acad. des Sciences, année 1769, p. 233.

rising ground is crowned with calcarious rocks, the strata of which, when taken together, are 54 feet thick. They every where rest upon a mass of clay, which, of course, before reaching the level of the river, is 86 feet thick. My garden, which is surrounded with several terraces, is situated on the top of this rising ground. From twenty-five to twenty-six fathoms of the last terrace-wall on the north-east side, where the declivity is greatest, gave way all at once, carrying along the inferior ground which would have gradually descended to the level of the ground near the river, if its progressive motion had not been prevented by taking down the whole wall. This wall was seven feet thick and founded on clay. The movement of the earth was very slow: I perceived that it was evidently occasioned by the insinuation of water. All the water which falls upon the platform on the top of this rising ground, penetrates through the fissures of the rocks, and reaches the clay upon which they rest: Of this fact we are ascertained by two wells dug from the top of the rock to the clay. All the rain-water, therefore, which falls upon this platform and the adjacent terraces, collect upon the clay where the perpendicular fissures of the rock terminate. The water gives rise to small rills in different places, which are rendered still more apparent by several wells dug below the rocks. Wherever this mass of clay is cut

cut by ditches, we see the water filtrating from above. It is not, therefore, surprising that walls, however solid, should slip upon this first bed of moist clay, if they are not founded much lower, as I have done in rebuilding them. The same thing, however, has happened on the north-west side, where the declivity is gentler, and no rills of water appear. The clay had been removed at the distance of twelve or fifteen feet from a great wall, of eleven feet thick, thirty-five feet high, and twelve fathoms long. This wall is constructed of good materials, and has subsisted more than nine hundred years. The cut from which the clay was removed, though not above four or five feet deep, has produced a movement in this immense wall. It declines from the perpendicular about fifteen inches, and I could only prevent its downfall by abutments of seven or eight feet thick, and founded at the depth of fourteen feet.

From these facts I drew the following conclusion, which is not so interesting at present as it would have been in ages that are past, that there is not a castle or fortress situated upon heights, which might not be easily tumbled into the plain by a simple cut of ten or twelve feet deep and some fathoms wide. This cut should be made at a small distance from the last wall, and upon that side where the declivity is greatest. This method, of which the ancients never dreamed,

dreamed, would have saved them the operation of battering-rams and other engines of war; and, even at present, might be employed, in many cases, with advantage. I am convinced by my eyes, that, when these walls split, if the cut made for rebuilding them had not been speedily filled with strong mason-work, the ancient walls, and the two towers that have subsisted in good condition nine hundred years, and one of which is 125 feet high, would have tumbled into the valley, along with the rocks upon which they are founded. As most of our hills composed of calcarious stones rest upon a clay base, the first strata of which are always more or less moistened with the waters that filtrate through the crevices of the rocks, it appears to be certain, that, by exposing these moistened beds to the air by a cut, the whole mass of rocks and earth resting upon the clay would slip, and in a few days tumble into the cut, especially during wet weather. This mode of dismantling a fortress is more simple than any hitherto invented; and experience has convinced me that its success is certain.

II.

Of Turf.

TO what I have formerly remarked concerning turf, I shall subjoin the following facts :

In the jurisdiction of Bergues-Saint-Winock, Furnes, and Bourbourg, we find turf at three or four feet below the surface. These beds of turf are generally two feet thick, and are composed of corrupted wood, of entire trees with their branches and leaves, and particularly of filberds which are known by their nuts, and the whole is interlaced with reeds and the roots of plants.

What is the origin of these beds of turf, which extend from Bruges through the whole flat country of Flanders as far as the river Aa, between the downs and the high country in the environs of Bergues? &c. In remote ages, when Flanders was only a vast forest, a sudden inundation of the sea must have deluged the whole country, and, in retiring, deposited all the trees, wood, and twigs, which it had eradicated and destroyed in this lowest territory of Flanders ; and this event must have happened in the month of August or September ; because we still find the leaves of trees, as well as nuts on the filberds. This inundation must have taken place long before
that

that province was conquered by Julius Caesar, since no mention is made of it in the writings of the ancients *.

In the bowels of the earth, we sometimes find vegetables in a different state from that of common turf. For example, in Mount Ganelon, near Compeigne, we find, on one side of the mountain, quarries of fine stones and the fossil oysters formerly mentioned, and, on the other side, we meet with a bed of the leaves of all kinds of trees, and also reeds, the whole blended together and inclosed in mud. When these leaves are stirred, we perceive the same musty odour which we feel on the margin of the sea; and these leaves preserve their odour during several years. Besides, the leaves are not destroyed; for we can easily distinguish their species: They are only dry, and slightly united to each other by the mud †.

‘ We distinguish,’ M. Guettard remarks, ‘ two species of turf: The one is composed of ‘ marine, and the other of terrestrial plants. We ‘ suppose the first to have been formed when ‘ the sea covered all those parts of the earth ‘ which are now inhabited. The second is supposed to have been superinduced upon the former. According to this system, it is imagined ‘ that

* Mem. pour la subdelegation de Dunkerque, relativement à l’Hist. Nat. de ce canton.

† Lettre de M. Lefchevin à M. de Buffon; *Compeigne*, 8. Aout. 1772.

‘ that the currents carried the sea-plants into the
 ‘ hollows formed by the mountains, which were
 ‘ elevated above the waters, and, after being
 ‘ tossed about by the waves, were deposited in
 ‘ the hollows.

‘ This origin of turf is not impossible : The
 ‘ great quantity of sea-plants is sufficient to ac-
 ‘ count for the phaenomenon. The Dutch e-
 ‘ ven alledge, that the goodness of their turf is
 ‘ owing to the bitumen with which the sea-
 ‘ water is impregnated, and that they were form-
 ‘ ed by sea-weeds.

‘ The turf-pits of Villeroy are situated in the
 ‘ valley through which the river Effone runs ;
 ‘ and part of this valley extends from Roissy to
 ‘ Escharcon. It is even near Roissy that
 ‘ turfs were first dug. But those near
 ‘ Escharcon are the best.

‘ The meadows where turf is dug are open
 ‘ and bad : They are filled with rushes, horse-
 ‘ tail, and other plants which grow in bad soils.
 ‘ These meadows are dug to the depth of eight
 ‘ or ten feet. Next to the upper stratum,
 ‘ there is a bed of turf about a foot thick, and
 ‘ impregnated with river and land-shells. . . .

‘ This bed of turf filled with shells is com-
 ‘ monly earthy : Those which succeed are near-
 ‘ ly of the same thickness, and are always better
 ‘ as we descend. These turfs are of a blackish
 ‘ brown colour, intermixed with reeds, rushes,
 ‘ and

‘and other plants. We see no shells in these beds. . . .

‘In masses of turf we sometimes find the stems of willow and poplars, and sometimes the roots of these and similar trees. On the Escharcon side, an oak was discovered at the depth of nine feet. It was black and almost corrupted. It crumbled into dust, after being exposed to the air. Another was found, on the Roissy side, between the soil and the turf, at the depth of two feet. Near Escharcon, the horns of a stag were found three or four feet below the surface. . . .

‘Turfs are perhaps equally abundant in the environs of Etampes, as near Villeroy. These turfs contain but very little moss. Their colour is a fine black. They are heavy, and burn well in an ordinary fire. Good charcoal might be made of them. . . .

‘The turfs in the neighbourhood of Etampes may be considered as a continuation of those of Villeroy. In a word, all the meadows adjacent to the river of Etampes are probably full of turf. The same remark is applicable to the meadows through which the river Eſſone runs: These meadows produce the same plants as those of Etampes and Villeroy *.’

According to this author, there are in France a number of places from which turf may be obtained,

* Mem. de l’Acad. des Sciences, année 1761, p. 380.—397.

tained, as at Bourneville, at Croué, near Beauvais, at Bruneval, in the environs of Péronne, in the diocese of Troyes in Champagne, &c. This combustible substance would be a great resource, if it were used in such places as want wood.

There are likewise turfs near Vitry-le-françois, and in the morass along the Marne. These turfs are good, and contain great quantities of acorn shells. The marsh of Saint-Gon in the environs of Châlons is full of turf, which the inhabitants will soon be obliged to use for want of wood *.

III.

Of Subterraneous, Petrified, and Charred Wood.

‘ IN the territories of the Duke of Sax-Cobourg, which lie on the frontiers of Franconia and Saxe, and at some leagues from the town of Cobourg, there were found; at a small depth, whole trees so completely petrified, that they were as beautiful and hard as agates. Some specimens of them were given by the Princes of Saxe to M. Schoepfin, who transmitted

* Note communicated to M. de Buffon, by M. Greignon, Aug. 6. 1777.

‘ted two of them to M. de Buffon for the royal
‘cabinet. Vases and other beautiful utensils
‘have been made of this petrified wood *.’

Wood in its natural state has likewise been found at great depths. M. du Verny, an officer of artillery, sent me some specimens of it, accompanied with the following letter :
‘The town of Fère, in the garrison of which I
‘am stationed, on the 15th of August 1753, ordered a search to be made for water by means
‘of boring : At 39 feet below the surface, they
‘found a bed of marl, which they continued to
‘pierce for 121 feet : Hence, at the depth of
‘160 feet, they found, at two different trials,
‘the augre filled with marl, intermixed with
‘numerous fragments of wood, which every
‘person easily recognised to be oak. I send
‘you two specimens of this wood. During the
‘succeeding days operations, they continued to
‘find the same marl, but not so much mixed
‘with wood, as far as the depth of 210 feet,
‘where they ceased to bore †.’

‘In the territory of Cobourg, which is a
‘branch of the house of Saxe, we find,’ M. Justi remarks, ‘petrified wood of a prodigious
‘size. In the mountains of Misnia, entire trees
‘have been dug out of the earth, which were
‘converted into very fine agate. The Imperial
cabinet

* Lettre de M. Schoepflin, *Strasbourg*, Sept. 24. 1746.

† Lettre de M. Bresse du Verny; *La Fère*, Nov. 14. 1753.

‘ cabinet of Vienna contains many petrifications
 ‘ of this kind. A great log of this wood was
 ‘ sent to the same cabinet : The part which had
 ‘ been wood was changed into a beautiful agate
 ‘ of a grayish black colour ; and, instead of bark,
 ‘ the trunk was surrounded with a belt of fine
 ‘ white agate.

‘ The present Emperor wished that a method
 ‘ of ascertaining the age of petrifications might
 ‘ be discovered. He ordered his
 ‘ ambassador at Constantinople to ask per-
 ‘ mission to take up from the Danube one of the
 ‘ piles of Trajan’s bridge, which is some miles
 ‘ below Belgrade. This permission being grant-
 ‘ ed, one of the piles was drawn up, which it
 ‘ was imagined would have been petrified by
 ‘ the water. But, after such a lapse of time, it
 ‘ was discovered that the process of petrification
 ‘ had made very little progress. Though this
 ‘ pile had remained in the Danube above 1600
 ‘ years, the petrification had not proceeded above
 ‘ three quarters of an inch, and even less. The
 ‘ rest of the wood was very little altered, and
 ‘ had only begun to be calcined.

‘ If a just conclusion, with regard to all other
 ‘ petrifications, could be drawn from this single
 ‘ fact, Nature would perhaps require fifty thou-
 ‘ sand years to change trees, of the size of those
 ‘ found petrified in certain places, into stones.
 ‘ But, in particular situations, many causes may
 ‘ concur in hastening the process of petrifica-
 ‘ tion.

‘ At

‘ At Vienna there is to be seen a petrified
 ‘ log, which was brought from the Carpathian
 ‘ mountains in Hungary. Upon this log the
 ‘ marks of the hatchet, which had been made
 ‘ before its petrification, are distinctly visible ;
 ‘ and these marks are so little altered by the
 ‘ change the wood has undergone, that we per-
 ‘ ceive they have been made by a small instru-
 ‘ ment.

‘ Besides, it appears that petrified wood is not
 ‘ so rare as is commonly imagined ; and that,
 ‘ to discover it in many places, requires only
 ‘ the nice eye of a naturalist. Near Mansfeld,
 ‘ I saw a great quantity of petrified oak in a
 ‘ place where many people daily pass, without
 ‘ perceiving this phaenomenon. Some logs were
 ‘ entirely petrified, and in these we distinctly
 ‘ perceived the rings formed by the annual
 ‘ growth, the bark, the place where they were
 ‘ cut, and all the characters of oak-wood *.’

M. Clozier, who found different pieces of pe-
 trified wood upon the hills in the neighbour-
 hood of Etampes, and particularly on that of
 Saint-Symphorien, imagined that these frag-
 ments might have proceeded from some petrifi-
 ed trunks in the mountains. He, therefore,
 caused pits to be dug in a part of the mountain
 of Saint-Symphorien that had been pointed out
 to him. After digging several feet deep, he first
 discovered

* Journal étranger, mois d’Octobre 1756, p. 160.

discovered a petrified root, which led him to the trunk of a tree of the same species.

This root, from its extremity to its junction with the trunk, was, says M. Clozier, five feet in length; there were other five roots, but not equally long. . . .

The middling and small roots were not petrified, or at least their petrification was so brittle, that they remained in the sand, where the trunk was in the form of powder or ashes. It is reasonable to think, that, when the process of petrification was communicated to these roots, they had been almost corrupted, and that the ligneous parts of which they were composed, being too much separated by petrification, could not acquire the degree of solidity necessary to a genuine petrification. . . .

The thickest part of the trunk was near six feet in circumference. Its length was three feet ten inches, and its weight was from five to six hundred pounds. The trunk, as well as the roots, had all the appearance of wood, as the bark, the inner rhind, the solid and corrupted wood, the holes of large and small worms, and even the excrements of these worms. All these parts were petrified, but were not so solid and hard as the ligneous body, which had been perfectly found when the process of petrification commenced. The ligneous body is converted into a real flint of various colours, which strikes

fire with steel, and produces, after being struck or rubbed, a very strong smell of sulphur. . . .

This petrified trunk was bedded in a horizontal direction. . . . It was covered with more than four feet of earth, and its root was not above two feet below the surface *.

M. l'Abbé Mazéas, who discovered, at half a mile from Rome, a quarry of petrified wood, expresses himself in the following terms :

' This quarry of petrified wood forms a succession of hillocks in the front of Monte-Mario, on the other side of the Tiber. . . . Of these fragments of wood, irregularly heaped upon each other, some have the appearance of a hard dry earth, which seems not to be fit for the nourishment of vegetables : Others are petrified, and have the colour, the brilliancy, and the hardness of the resin known in the shops by the appellation of *colophanus*. This petrified wood is found in a soil similar to the former, but more moist. Both are perfectly well preserved. The whole are reduced, by calcination, into a true earth ; and none of them produce allum, either by the application of fire, or by combining them with the vitriolic acid †.'

M. du Monchau, a physician and expert naturalist, has sent me, for the royal cabinet, a piece

* Mem. des Savans étrangers, tom. 2. p. 598.—604.

† Mem. des Savans étrangers, tom. 5. p. 388.

piece of petrified wood with the following historical account :

‘ The piece of petrified wood, which I have
 ‘ the honour of transmitting to you, was found
 ‘ at the depth of more than 150 feet below the
 ‘ surface. . . . Last year (1754) when digging
 ‘ a pit in quest of coal, at Notre-Dame-au-bois,
 ‘ a village situated between Condé, Saint-Amand,
 ‘ Mortagne, and Valenciennes, we found, a-
 ‘ bout 600 fathoms from Elcaut, and after pas-
 ‘ sing three water-levels, first seven feet of
 ‘ rock or hard stone called *tourtia* in the lan-
 ‘ guage of colliers ; afterwards, when we ar-
 ‘ rived at a marshy earth, we found, at the depth
 ‘ of 150 feet, as already remarked, the trunk of a
 ‘ tree of two feet in diameter, which lay across
 ‘ the pit, and, of course, we were prevented
 ‘ from measuring its length. It rested upon a
 ‘ large free-stone ; and many pieces were cut
 ‘ off from this trunk by the curious. The small
 ‘ fragment I have the honour of sending you
 ‘ was cut off from a specimen given to M. Lau-
 ‘ rent, a learned mechanic. . . .

‘ This wood seemed rather to have been convert-
 ‘ ed into coal than petrified. How could a tree be
 ‘ sunk so deep into the earth ? Has the soil in
 ‘ which the tree was found been formerly as low ?
 ‘ If that is the case, how could this soil be aug-
 ‘ mented 150 feet ? From whence did all this
 ‘ earth proceed ?

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‘ The

‘ The seven feet of *tourtia* observed by M. Laurent, which exists also in all the coal-mines for ten leagues round, have, according to the above supposition, been produced posterior to this accumulation of earth.

‘ I leave this matter, Sir, to your decision : You are so intimately acquainted with Nature, that none of her mysteries can be long concealed from you ; and I have no doubt that you will be able to explain this wonderful phenomenon *.’

M. Fougereux de Bondaroy, of the Royal Academy of Sciences, relates several facts concerning petrified wood, which merit attention.

‘ All the fibrous stones,’ he remarks, ‘ which have some resemblance to wood, are not petrified wood. But there are many others which must be recognised as such, especially if we attend to the peculiar organization of vegetables.

‘ Facts are not wanting to prove that wood may be converted into stone, with as much ease at least as several other substances which incontestibly undergo this transmutation. But it is difficult to explain how this effect is produced. I hope I may be permitted to hazard some conjectures on the subject, which I shall endeavour

* Lettre de M. Dumonchau à M. de Buffon ; Douai, Jan. 29. 1755.

' endeavour to support by facts and observa-
' tions.

' We find wood which may be considered as
' only half petrified, and not much heavier than
' common wood. Specimens of this kind are
' easily divided into plates, or even into fila-
' ments, like certain corrupted timber. Others
' are more petrified, and have the weight, the
' hardness, and the opacity of free-stone. O-
' thers, whose petrification is still more perfect,
' admit the same polish as marble; while others
' acquire that of fine oriental agates. I have an
' excellent specimen sent from Martinico to M.
' du Hamel, which is converted into a most
' beautiful sardonix. Lastly, we find wood
' changed into slate. Among these specimens,
' there are some which have retained the orga-
' nization of wood so completely, that we dis-
' cover with a lens every appearance exhibited
' in unpetrified wood.

' We have seen some specimens encrusted
' with a sandy iron ore, and others penetrated
' with a substance which, being composed of sul-
' phur and vitriol, makes them approach the
' state of pyrites. Some of them are, if we
' may use the expression, larded with a very
' pure iron ore; and others are traversed by
' veins of very black agate.

' We find pieces of wood, one part of which
' is converted into a stone, and the other into

agate: The part converted into stone is tender; but the other has the hardness peculiar to precious stones.

But, how should certain pieces, though converted into hard agate, preserve the distinct characters of organization, as the concentric circles, the insertions, the extremities of the tubes destined to transmit the sap, the bark, the inner rind, and the wood? If the vegetable substance were entirely destroyed, we should only see an agate, without any of the organic characters formerly mentioned. To preserve this appearance of organization, if we suppose that the wood subsists, and that the pores alone are filled with the petrifying juice, it should appear, that the vegetable parts might be extracted from the agate. But I could never make any progress in this operation: I, therefore, think, that the specimens in question retain no parts which have preserved the nature of wood. To give perspicuity to my idea, I beg the reader to recollect, that, when a piece of wood is distilled in a retort, the coal which remains after distillation is not a sixth part of the original weight of the wood. When this coal is burnt, we obtain only a small quantity of ashes, which will still diminish after the lixivial salts are abstracted.

This small quantity of ashes being the only fixed part, the chemical analysis proves, that
the

‘ the fixed parts of a piece of wood are really
 ‘ very trifling, and that the greatest portion of
 ‘ vegetable matter is destructible, and may be
 ‘ gradually carried off, as the wood corrupts.

‘ Now, if we consider that the greater part of
 ‘ the wood is destroyed, and that what remains
 ‘ is a light earth, and easily permeable by the
 ‘ petrifying juice, its conversion into stone, a-
 ‘ gate, or sardonix, will not be more difficult to
 ‘ conceive than that of bole, clay, or any other
 ‘ earth. The only difference is, that the vege-
 ‘ table earth preserves the appearance of organi-
 ‘ zation, and the petrifying juice insinuates into
 ‘ its pores, without destroying its original cha-
 ‘ racters *.’

Some facts and observations remain still to be added. In August 1773, at Montigni-sur-Braine, in the district of Chalon and jurisdiction of Auxonne, when digging a copper mine, the workmen, at the depth of 33 feet, found a tree lying on its side; but the species of it could not be discovered. The superior strata seemed to have never been touched by the hand of man; for, below the soil, there was a bed of 8 feet of clay; then 10 feet of sand; then a bed of fullers earth about 6 or 7 feet; then another bed of the same mixed with stones; and, lastly, a bed of black sand of 3 feet. The tree was
 found

* Mem. de l'Acad. des Sciences, année 1759, p. 431.
 452.

found in the fullers earth. The river Braine is to the east, and not above a gun-shot from this place. It runs in a meadow 80 feet lower than the site of the copper*.

M. de Grignon informed me, that, on the borders of the Marne, near St Dizier, there is a bed of pyritous wood, the organization of which is apparent. This bed is situated under a stratum of free-stone, which is covered with a stratum of pyrites, and above the pyrites is a stratum of lime-stone. The bed of pyritous wood lies upon a blackish clay.

He likewise found, in the pits dug for discovering the subterraneous town of Châtelet, instruments of iron with wooden handles. He remarked that this wood was converted into a genuine iron-ore of the hematites species. The organization of the wood was not destroyed; but it was brittle, and its whole texture was as close as that of the hematites. These iron instruments with wooden handles had been buried in the earth sixteen or seventeen hundred years. The conversion of the wood into hematites had been affected by the decomposition of the iron, which had gradually filled all the pores of the wood.

IV.

* Lettre de Mad. la Comtesse de Clermont-Montoison à M. de Buffon.

IV.

Of Bones sometimes found in the interior parts of the Earth.

‘ IN the parish of Haux, which is situated
‘ between two seas, and about half a league
‘ from the port of Langoiran, a point of a rock,
‘ of 11 feet high, detached itself from the coast,
‘ which was formerly 30 feet high. By its fall
‘ it spread over the valley a great quantity of a-
‘ nimal bones or fragments of bones, some of
‘ which were petrified. That they are bones is
‘ unquestionable; but it is difficult to ascertain the
‘ animals to which they belong. The greatest
‘ number consists of teeth; some of them perhaps
‘ belong to the ox or horse; but, without marking
‘ the difference in figure, most of them are larger
‘ than the teeth of these animals. There are
‘ likewise thigh or leg-bones, and a fragment
‘ of a stag or elk’s horn. The whole are cover-
‘ ed with common earth, and situated between
‘ two strata of rock. We must suppose that the
‘ carcasses of animals have been thrown into a
‘ hollow rock, and, after the flesh had corrupt-
‘ ed, a rock of 11 feet high had been formed
‘ above them, which would require the opera-
‘ tion of many ages. . . .

‘ The Gentlemen of the Academy of Bour-
‘ deaux, who examined these bones with phi-
‘ losophical

‘lofophical accuracy, difcovered, that, when a
 ‘number of fragments were put on a very
 ‘brisk fire, they were converted into a fine Tur-
 ‘quois blue; and that fome portions became fo
 ‘hard, that, when cut by a lapidary, they re-
 ‘ceived a fine polifh. . . . It muft alfo be re-
 ‘marked, that bones which evidently belonged
 ‘to different animals were equally converted in-
 ‘to Turquois *.’

‘On the 28th of January 1760,’ fays M. de
 Guettard, ‘there were found, 160 fathoms a-
 ‘bove the mineral baths, bones included in a
 ‘rock with a gray furface. This rock was nei-
 ‘ther laminated nor confifted of feparate ftrata,
 ‘but was one continued mafs of ftone. . . .

‘After having, by means of gun-powder, pe-
 ‘netrated five feet deep into this rock, we found
 ‘a great number of human bones belonging to
 ‘every part of the body, as jaw-bones with their
 ‘teeth, bones of the arms, thighs, limbs, ribs,
 ‘rotulae, &c. jumbled together in the greateft
 ‘diforder. Entire fkulls, or portions of them,
 ‘chiefly prevailed.

‘Belide thefe human bones, we met with
 ‘feveral fragments which could not be afcribed
 ‘to man. In fome places, they are in conti-
 ‘nued maffes, and in others more difperfed. . .

‘When we arrived at the depth of four feet
 ‘and a half, we found fix human heads in an
 ‘inclined

* Hift. de l’Acad. des Sciences, année 1719, p. 24.

' inclined position. In five of these heads, the
 ' occiput with its appendages, except the bones
 ' of the face, were preserved. This occiput was
 ' partly encrusted with stone, its cavity was fill-
 ' ed with stone, and had assumed the same mould
 ' or figure. In the sixth head, the face is en-
 ' tire: It is broad in proportion to its length,
 ' We easily distinguish the form of the fleshy
 ' cheeks. The eyes are shut, pretty long, but
 ' narrow. The front is large, and the nose ve-
 ' ry flat, but well formed; the middle line is
 ' distinguishable. The mouth is well made,
 ' and shut; the upper lip is a little thick in pro-
 ' portion to the under. The chin is well pro-
 ' portioned, and the whole muscles are strongly
 ' marked. The colour of the head is reddish,
 ' and resembles those of the Tritons feigned by
 ' painters. Its substance is similar to that of
 ' the stone in which it was found; it is, proper-
 ' ly speaking, only the mask of the natural
 ' head.'

The above relation was sent by M. le Baron
 de Gaillard-Lonjumeau to Madame de Boiss-
 jourdain, who transmitted it to M. Guettard, with
 some specimens of the bones. That these bones
 were really human, is a very doubtful point;
 ' for every appearance in this quarry,' M. de
 Lonjumeau remarks, ' announces that it has
 ' been formed of relicks of bodies broken in
 ' pieces, and which had been long tossed about
 ' by

‘ by the waves of the sea before they were collected into one heap. As this mass of bones lies horizontally, and has been successively covered with stony matter, it is easy to conceive how a mask was formed on the faces of those heads, the flesh having little time to corrupt, especially when the bodies were buried under the water. We may, therefore, reasonably conclude, that these heads were not human. . . . They rather seem to be the heads of those fishes, whose teeth are found in the same parts of the stones along with the bones supposed to belong to the human species.

‘ It appears that the collection of bones in the environs of Aix, are similar to those discovered some years ago by M. Borda near Dax in Gascony. The teeth discovered at Aix, by the description given of them, seem to resemble those found at Dax, of which an under jaw is still preserved. This jaw unquestionably belongs to a large fish. . . . I must, therefore, conclude, that the bones in the quarry of Aix are similar to those discovered at Dax; . . . and that these bones, whatever they are, should be referred to the skeletons of fishes rather than to those of man. . . .

‘ One of the heads in question was about seven and a half inches long by three and some lines broad. Its figure is that of an oblong globe, flat at the base, thicker at the posterior than

‘ than the anterior end, and divided in the broad-
 ‘ est part by seven or eight bands from seven
 ‘ to twelve lines wide. Each band is likewise
 ‘ divided into two equal parts by a slight fur-
 ‘ row. The bands extend from the base to the
 ‘ summit. Those of one side are separated from
 ‘ those of the other by another and deeper fur-
 ‘ row, which gradually enlarges from the ante-
 ‘ rior to the posterior part.

‘ From this description we cannot recognize
 ‘ the mould of a human head. The bones of
 ‘ man’s head are not divided into bands. The
 ‘ human head is composed of four principal
 ‘ bones, the figures of which appear not in the
 ‘ mould above described. It has not an interior
 ‘ crest which extends longitudinally from the
 ‘ anterior to the posterior part, and divides it
 ‘ into two equal parts, which might give rise to
 ‘ the furrow on the superior part of the stony
 ‘ mould.

‘ These considerations induce me to think,
 ‘ that this substance is rather the body of a nau-
 ‘ tilus than a human head. There are nautili
 ‘ actually divided into bands or bucklers like this
 ‘ mould. They have a channel or furrow which
 ‘ runs along the whole curvature, and divides
 ‘ them into two, from which the stony furrow
 ‘ might derive its origin *,’ &c.

I

* Mem. de l’Acad. des Sciences, année 1760, p. 209.
 —218.

I am persuaded, as well as M. le Baron de Lönjumeau, that these heads never belonged to men, but to animals of the seal kind, to sea-otters, and to sea lions or bears. It is not at Aix or Dax alone, that the heads and bones of these animals are found in rocks and caverns. His Highness the present Prince Margrave of Anspach, who to great affability unites a remarkable taste for knowledge, has been so obliging as to give me, for the Royal Cabinet, a collection of bones from the caverns of Gailenrente in his Margraviate of Bareith. M. Daubenton has compared these bones with those of the common bear, from which they differ only by being larger. The head and teeth are longer and thicker; and the muzzle is longer and more protuberant than in our largest bears. In this collection, with which this noble Prince has enriched our cabinet, there is a head which naturalists have denominated *the head of M. de Buffon's small seal*; but, as we know not the form and structure of the heads of sea lions, bears, and large and small seals, we shall suspend our judgment concerning the animals to which these fossil bones have appertained.

A D D I.

*ADDITIONS to the Article, Of the
Changes of Sea into Land, Vol. I. p. 483.*

IN traversing the coasts of France, we perceive that a part of Brittany, Picardy, Flanders, and Lower Normandy, have very recently been deserted by the sea; because, through all this extent of country, we still find great quantities of oysters, and other shells, in their natural state. We are certain, from experience, that, for a century past, the sea has been retiring from the coast of Dunkirk. When the moles of this port were constructing in the year 1670, the fort of Good-hope, which terminate one of these moles, was built upon piles a great way beyond the low water-mark. But, at present, the water never advances nearer this fort than 300 fathoms. In 1714, when the new harbour of Mardik was deepening, the moles were likewise carried beyond the low water-mark; but now, when the tide is ebb, there is a dry space of more than 500 fathoms. If the sea continues thus gradually to retire, Dunkirk, like Aiguemortes, will, in a few centuries, be no longer a
sea-

sea-port. If the sea has lost ground so considerably in our times, how far must it have retired since the beginning of the world * ?

The bare inspection of Saintonge is sufficient to convince us, that it was formerly covered by the sea. The ocean having abandoned these lands, the Charente followed as the waters retired, and formed a river where formerly there was only a great lake or morafs. The country of Aunis, which was anciently covered by the sea and stagnant waters, is one of the most recent lands of France. It is even probable that this territory was a morafs about the end of the fourteenth century †.

It appears, therefore, that the ocean, during some centuries, has retired many feet from all our coasts ; and if we examine those of the Mediterranean, from Rouffillon to Provence, we shall find that this sea has likewise retreated nearly in the same proportion. These facts render it evident, that the circumference of all the coasts of Spain and Portugal, as well as those of France, is greatly extended. The same observation has been made with regard to Sweden, where some philosophers have conjectured, that, in the course of 4000 years, the Baltic, the depth of which exceeds not thirty fathoms, will be totally abandoned by the waters.

If

* Mem. pour la subdelegation de Dunkerque, relativement à la Hist. nat. de ce canton.

† Extrait de l'hist. de la Rochelle, art. 2. et 3:

If similar observations were made in every country, I am persuaded, that, in general, the sea would be found to have retired from every coast. The same causes which produced its first retreat and successive sinking, are not absolutely annihilated. In the beginning, the sea was two thousand fathoms above its present level. The immense swellings on the surface of the globe, which first subsided, made the waters sink, at first rapidly, and afterwards in proportion as the more inconsiderable caverns gave way. The sea, of course, was proportionally depressed; and, as many caverns still exist, which must, from time to time, sink, either by the action of volcano's, by the force of water, or by earthquakes, we may with certainty predict, that the ocean will continue to retire, and, consequently, that the extent of all our continents will be gradually augmented.

VOL. IX: R FACTS

FACTS AND ARGUMENTS,

IN SUPPORT OF THE

COUNT DE BUFFON'S

EPOCHS OF NATURE.

THE treatise composed by the Count de Buffon, under the title of *Les Epoques de la Nature*, is exceedingly ingenious. It is intended to establish by facts and reasoning, his theory of the formation of the Planets*. But as this theory, however it may be relished on the Continent, is perhaps too fanciful to receive the general approbation of the cool and deliberate Briton, the translator has been advised not to render it into English. Many of the facts, however, are too important to be omitted. Instead of a regular translation, therefore, he shall give

* See vol. i. p. 59. of this work.

give a generall view only of the positions laid down in this treatise, together with the most interesting facts produced in support of these positions.

The Count de Buffon begins his subject with a preliminary discourse, in which he endeavours to unfold the different changes the terrestrial globe has undergone from its first projection out of the sun to the present time. In this discourse the author observes the following order: 1. He mentions such facts as may lead us to the origin of Nature. 2. He marks those monuments which ought to be regarded as the evidences of the first ages. 3. He collects such traditions as may convey some idea of the ages which succeeded. After which, says he, we shall endeavour to connect the whole by analogies, and to form a chain which, from the commencement of time, shall descend to the present days.

FIRST FACT.

The earth is elevated at the Equator and depressed at the poles, in the proportion required by the laws of gravity and of the centrifugal force.

R 2

SECOND

SECOND FACT.

The earth possesses an internal heat which is proper to itself, and independent of that communicated to it by the rays of the sun.

THIRD FACT.

The heat conveyed to the earth by the sun is very small when compared with the heat proper to the globe; and this heat transmitted by the sun would not alone be sufficient to support animated nature.

FOURTH FACT.

The materials of which the earth is composed are, in general, of a vitreous nature, and the whole of them may be converted into glass.

FIFTH FACT.

We find on the whole surface of the earth, and even on the mountains, to the height of 1500 and 2000 fathoms, an immense quantity of shells and other relicks of marine productions.

The

The first fact, namely, the elevation of the globe at the Equator and its depression at the poles, has been mathematically demonstrated and physically proved by the theory of gravitation, and by experiments with the pendulum. The figure of the earth is precisely the same which a fluid globe revolving round its axis with equal celerity would assume. Hence the matter of which the earth is composed was in a state of fluidity the moment it assumed its form, and this moment happened whenever it began to turn round its own axis. Now, though heat is the general cause of fluidity, since water itself, without heat, would form a solid mass, we have two methods of conceiving the possibility of the primitive fluid state of the earth. The first is the solution of terrestrial matters in water; and the second is their liquefaction by fire. But most of the solid matters of which the earth is composed are not soluble in water; and, at the same time, the quantity of water, in proportion to that of dry and solid matter, is so small, that it is impossible the one could be dissolved by the other. Of course, as this state of fluidity could not be effected by dissolution or maceration in water, this fluidity must have been produced by the operation of fire.

This conclusion assumes a new degree of probability from the second fact, and is rendered certain by the third. The internal heat

of the globe, which still subsists partially, and is greater than that afforded by the sun, shews that this primitive fire is not yet nearly dissipated. The surface of the earth is colder than its interior parts. Uncontrovertible and reiterated experiments evince, that the whole mass of the globe has a heat proper to itself, and totally independent of that of the sun. This heat is rendered evident by comparing our winters with our summers *; and it is still more palpable when we penetrate into the bowels of the earth. At equal depths, it is invariably the same, and it appears to augment in proportion as we descend.

‘ At no great depth, we perceive a heat which
 ‘ never varies with the temperature of the
 ‘ atmosphere. We know, that the liquor of the
 ‘ thermometer remains, during the whole year,
 ‘ at the same height in the caves of the Observa-
 ‘ tory, which exceed not 84 feet or 14 fathoms
 ‘ below the surface. Hence this point has
 ‘ been fixed as the mean temperature of our
 ‘ climate. This heat commonly continues
 ‘ nearly the same from 14 or 15 to 60, 80, or
 ‘ 100 fathoms, more or less, according to cir-
 ‘ cumstances, as we experience in our mines.
 ‘ Beyond this depth it augments, and some-
 ‘ times

* See *Suppl. tom. i. part. 1.* and particularly the two *Memoirs sur la temperature des planètes*, *Suppl. tom. 2.*

' times becomes so great, that the workmen
 ' could not support it, if they were not cooled
 ' by fresh air, either from air-pits, or from falls
 ' of water. . . M. de Genfanne found, that,
 ' in the mines of Giromagny, three leagues
 ' from B  fort, when the thermometer was car-
 ' ried 52 fathoms deep, it stood at 10 degrees,
 ' as in the caves of the Observatory ; that, at
 ' 106 fathoms, it stood at 10' degrees ; that,
 ' at 158 fathoms, it mounted to 15½ degrees ;
 ' and that, at 222 fathoms, it rose to 18½ de-
 ' grees *.'

' In proportion as we descend into the bow-
 ' els of the earth,' M. de Genfanne remarks,
 ' we perceive a sensible increase of heat. 1800
 ' feet below the level of the Rhine, at Hunin-
 ' guen in Alsace, I found, that the heat was so
 ' great as to produce a sensible evaporation
 ' from water. A detail of my experiments on
 ' this subject may be seen in the last edition of
 ' that excellent *Traité de la glace* composed
 ' by my deceased illustrious friend M. Dortous
 ' de Mairan †.'

' All the rich veins of every species of me-
 ' tal,' says M. Eller, ' are in the perpendicular
 ' fissures of the earth ; and the depth of these
 ' fissures cannot be ascertained. In Germany,
 ' some of them have been traced above 6000
 ' feet

* Differt. sur la glace, par M. Mairan, p. 60.

† Hist. Nat. de Languedoc, tom. 1. p. 24.

‘ feet deep. In proportion as the miners descend, they feel that the temperature of the air becomes always hotter *.’

Though our deepest mines and pits are inconsiderable excavations ; yet the internal heat is more sensibly felt in them than on the surface. We may, therefore, presume, that, if we could penetrate still deeper, this heat would increase, and that the parts near the centre of the earth are hotter than those more distant. This internal heat is likewise apparent from the temperature of the ocean, the waters of which, at equal depths, exhibit nearly the same heat as that of the interior parts of the earth. ‘ Having plunged a ‘ thermometer,’ M. Marfigli remarks, ‘ into the ‘ sea in different places and at different times, ‘ it was found that the temperature at 10, 20, ‘ 30, and 120 fathoms, was equally from 10 to ‘ $10\frac{3}{4}$ degrees †’. On this subject M. de Mairan judiciously remarks, ‘ that the hottest waters which are at the greatest depth, must, as ‘ being the lightest, continually ascend above ‘ those that are heavier. Hence, according to ‘ Marfigli’s observations, the temperature of this ‘ immense body of water must be always nearly equal, except near the surface, which is ‘ exposed

* Mem. sur la generation des metaux. Academie de Berlin, année 1733.

† L. Hist. physique de la mer par Marfigli, p. 16.

‘ exposed to the impressions of the air, where
 ‘ the water sometimes freezes before it has time
 ‘ to descend by its own weight and coolness *.’

Besides, it is easy to show, that the fluidity of the ocean ought not, in general, to be ascribed to the powers of the solar rays ; since we learn from experience, that the light of the sun does not penetrate the most limpid water above six hundred feet; and, of course, that its heat will not reach above a fourth part of that depth, or one hundred and fifty feet. The late M. Bouguer, a learned astronomer of the Royal Academy of Sciences, found, that, when sixteen pieces of common glass were applied to each other, and making a thickness of $9\frac{1}{2}$ lines, the light, in passing through these sixteen pieces of glass, was diminished 247 times. He then placed seventy-four pieces of the same glass, in a tube, and at some distance from each other. When this experiment was made, the sun was 50 degrees above the horizon. A very faint appearance of the sun’s disk was still perceptible through these 74 pieces of glass. The persons who attended him could likewise perceive, but with difficulty, a feeble light. But, when other three pieces of glass were added to the seventy-four. none of them could distinguish the smallest vestige of light. Hence,
 if

* Differt. sur la glace, p. 69.

if we suppose eighty pieces of the same glass, we have a thickness which will render it perfectly opaque.

From this analogy between the transparency of glass and water, M. Bouguer found, that, to render sea-water, which is the most limpid of all waters, perfectly opaque, a thickness of 256 feet is necessary, provided, by another experiment, the light of a flambeau was diminished in the proportion of 14 to 5 in traversing 115 inches of water contained in a tube of 9 feet 7 inches in length. Hence, according to M. Bouguer, no sensible light can pass deeper than 256 feet in water*.

It appears to me, however, that the conclusion drawn by M. Bouguer is very distant from the truth. His experiments should have been made with masses of glass of different thicknesses, and not with separate pieces applied to each other. I am persuaded that the sun's light would penetrate a greater thickness than that of these eighty pieces, which formed a thickness of no more than $47\frac{1}{2}$ lines, or near 4 inches. Now, though these pieces he employed were of common glass, it is certain that a solid mass of the same glass, of four inches thick, would not entirely intercept the light of the sun, especially as I know, by my own experience, that light passes easily through 6 solid inches

* *Essai d'Optique sur la gradation de la lumière*, p. 85.

inches of white glass. I believe, therefore, that the thicknesses assumed by M. Bouguer should be more than doubled, and that the light of the sun penetrates 600 feet deep into the waters of the ocean; for there is another inaccuracy in M. Bouguer's experiments. He did not make the light of the sun pass through his tube of 9 feet 7 inches long: He employed the light of a flambeau, and thence concluded the diminution to be in the proportion of 14 to 5. But I am persuaded, that, if the light of the sun had been employed, this diminution would not have been so great, especially as the light of a flambeau could only pass obliquely, whilst that of the sun, by passing directly, would have penetrated deeper by its incidence alone, independent of its purity and intensity. Thus, taking all circumstances into consideration, it appears, that, to approach the truth as near as possible, we should suppose, that the light of the sun penetrates the sea to the depth of 600 feet, and that its heat reaches 150 feet deep. The light and heat must here be understood as sensible degrees only of these qualities.

That the heat of the sun penetrates not above 150 feet deep in the waters of the ocean, I ascertained by analogy derived from an experiment which appears to be decisive. With a lens of 27 inches diameter by six inches thick at the centre, I perceived, that, by covering the
middle

middle part, the lens burnt only from the circumference as far as four inches thick, and that all the thicker part scarcely produced any heat. I then covered the whole lens, except an inch round the centre, and I found, that, after passing this thickness of six inches of glass, the light of the sun had no influence on the thermometer. Hence I am warranted to presume, that this same light, weakened by 150 feet thick of water, would not produce a perceptible degree of heat.

The light proceeding from the moon is unquestionably a reflected light of the sun. This light, however, has no sensible heat, even when the rays are collected into the focus of a burning-glass. Neither would the light of the sun have any heat, after passing through a certain depth of water; because it would then be equally feeble as that of the moon. I am, therefore, persuaded, that, by allowing the rays of the sun to pass through a large tube filled with water, and only 50 feet long, which is no more than a third of the depth I have supposed, this feeble light would produce no effect upon the thermometer, even though the liquor stood at the freezing point. From whence I may conclude, that, though the light of the sun penetrates 600 feet in the waters of the ocean, its heat would not reach one fourth part of that depth. All the waters below this point would
necessarily

necessarily freeze, unless there was an internal heat in the earth, which alone can maintain their fluidity. In the same manner, it is proved by experience that the heat of the solar rays penetrates not above 15 or 20 feet deep in the earth, since ice is preserved at these depths during the warmest summers. Hence, it is clear, that, below the basin of the sea, as well as under the superior strata of the earth, there is a perpetual emanation of heat, which supports the fluidity of the waters, and produces the temperature of the earth. In the interior parts of the earth, therefore, a heat exists which is proper to it, and which is totally independent of that communicated by the sun.

We might confirm this general fact by a number of particular ones. Every man has remarked, that the snow melts in all places where the vapours of the interior parts of the earth have a free issue, as over pits, covered aqueducts, vaults, cisterns, &c. while in all other places, where the earth, bound up by the frost, intercepts these vapours, the snow not only remains, but, instead of melting, freezes. This circumstance is alone sufficient to show, that these emanations from the internal parts of the earth have a real and sensible degree of heat.

With regard to the *fourth* fact: After the satisfactory proofs we have given in several articles of our *Theory of the Earth*, it is apparent, that

that the materials of which this globe is composed are of the nature of glass. This general truth, which we can prove by experience, was not altogether unknown to Leibnitz, a German philosopher, whose name will continue to be an honour to his country :

‘ Sane plerisque creditum et a sacris etiam
 ‘ scriptoribus insinuaturn est, conditos in abdito
 ‘ telluris ignis thesauros. . . Adjuvant vultus,
 ‘ nam omnis ex fusione SCORIAE VITRI est GE-
 ‘ NUS . . . Talem vero esse globi nostri superfi-
 ‘ ciem (neque enim ultra penetrare nobis datum)
 ‘ reapse experimur, omnes enim terrae et lapi-
 ‘ des igne vitrum reddunt . . . nobis satis est ad-
 ‘ moto igne omnia terrestria in VITRO FINIRI.
 ‘ Ipsa magna telluris ossa nudaque illae rupes at-
 ‘ que immortales silices cum tota fere in vitrum
 ‘ abeant, quid nisi concreta sunt ex fuis olim
 ‘ corporibus et prima illa magnaue vi quam
 ‘ in facilem adhuc materiam exercuit ignis na-
 ‘ turae . . . cum igitur omniaque non avolant
 ‘ in auras tandem funduntur, et speculorum im-
 ‘ primis urentium ope, vitri naturam sumant,
 ‘ hinc facile intelliges vitrum esse velut TERRÆ
 ‘ BASIN, et naturam ejus caeterorum plerumque
 ‘ corporum larvis latere. G. G. Leibnitii proto-
 ‘ gaea. *Goettingae*, 1749, pag. 4. et 5.’

The basis of minerals, of vegetables, and of animals, consists of vitrifiable matter ; for all their *residua* may be ultimately converted into glass.

glass. The substances called *refractory* by chymists, and which they consider as not fusible, because they resist the action of their furnaces without being changed into glass, may notwithstanding be vitrified by the more intense heat of burning glasses. Hence all the materials of this globe, at least all those which are known to us, have glass for their basis, and may be ultimately reduced to their primitive state.

We have, therefore, proved the original liquefaction by fire of the whole mass of this globe, agreeably to the most rigorous rules of logic: 1. *A priori*, by the first fact, namely, the elevation of the earth at the equator, and its depression at the poles. 2. *Ab actu*, by the second and third fact, namely, the internal heat of the globe which still subsists: 3. *A posteriori*, by the fourth fact, which shows the effect of this action of fire, i. e. glass in all terrestrial substances.

But, though the materials which compose this globe have originally been of a vitreous nature, and may all be reduced to glass, they ought to be distinguished from each other with regard to the different states in which they are found before they are converted into glass by the action of fire. They should, in the first place, be divided into vitrifiable and calcareous substances. The first undergo no change by fire, unless it be pushed to such a degree of intensity as is sufficient

ficient to reduce them to glass; but an inferior degree of heat reduces the others to lime. The quantity of calcarious substances, though very considerable, is small when compared to those which are vitrifiable. The *fifth* fact above laid down proves, that calcarious bodies have been formed at a different period, and by another element; and we evidently perceive, that all the matters which have not been produced by the immediate action of the primitive fire, have been formed by the intervention of water; because they are all composed of shells and other reliicks of marine bodies. Under the class of vitrifiable substances are comprehended pure rock, quartz, sand, free-stone, granite, slates, clays, metals, and metallic minerals. These substances form the genuine basis of the globe, and compose its principal and greatest part. The whole of them have been originally produced by the primitive fire. Sand is nothing but glass in powder; slates, dried clays, pure rock, free-stone, and granite; are only vitreous masses, or vitrifiable sand in a concreted form. Flints, crystals, metals, and most other minerals, are only distillations, exudations, or sublimations of the first matters, all of which unfold their primitive origin and their common nature, by their aptitude of being converted into glass.

But calcarious sand and gravel, chalk, brown free-stone, marble, alabastrar, calcarious spatha,
both

both opaque and transparent, in a word, every substance which can be converted into lime, do not at first exhibit their original nature. Though, like all the others, they proceed from glass, calcarious bodies have passed through filters, which have changed their appearance. They have been formed by water. They are composed entirely of madrepores, shells, and other relicks of aquatic animals, which alone are capable of converting fluids into solids, and of transforming the water of the sea into stone. Common marble and other calcarious stones are composed of entire shells and fragments of shells, of madrepores, asteroites, &c. all the parts of which are either still evident, or easily recognisable. Gravel is nothing but broken fragments of marble and calcarious stones which frost and the action of the air detach from the rocks; and they are equally convertible into lime. Lime may also be made of shells, chalk, and light land-stone. Alabaster, and those marbles which contain alabaster, may be regarded as large stalactites, which are formed at the expence of other marbles and common stones. Calcarious spatha is likewise formed by exudation or distillation from calcarious substances, in the same manner as rock-crystal originates from vitrifiable matters. All this may be proved by inspecting these different substances, and by examining attentively the great monuments of nature.

MONUMENT FIRST.

Shells and other productions of the ocean are found on the surface and in the interior parts of the earth ; and all the substances called *calcareous* are composed of the remains of these marine bodies.

MONUMENT SECOND.

In examining those shells and other marine productions found in France, Britain, German, and all the other parts of Europe, we discover, that most of the animals to which these remains have belonged, are not to be found in the adjacent seas, and that these species either have now no existence, or are to be found only in the southern seas. In the same manner, we see, in flates and other substances, at great depths, impressions of fishes and plants, none of which belong to our climates, and which either do not exist, or are to be met with in southern climates only.

MONUMENT THIRD.

In Siberia, and other northern regions of Europe and Asia, we find the skeletons, tusks, and bones of elephants, hippopotami, and rhinoceroses,

roses, in quantities sufficient to convince us, that these animals, which at present can propagate only in the southern regions, formerly existed and propagated in northern countries; and it has been remarked, that these remains of elephants and other terrestrial animals are found at inconsiderable depths below the surface. But shells and other marine bodies are buried deep in the interior parts of the earth.

MONUMENT FOURTH.

The tusks and bones of elephants, as well as the teeth of the hippopotamus, are found, not only in the northern parts of our Continent, but likewise in those of North America, though the species of the elephant and rhinoceros have now no existence in the New World.

MONUMENT FIFTH.

In the middle of Continents, and in places most remote from the sea, we find an infinite number of shells, most of which belong to animals actually existing in the southern ocean, and several others have no known representatives; so that their species seem to have been annihilated by causes till now unknown.

By comparing these monuments with the facts, we at once perceive, that the time when

vitriifiable substances were formed is much more remote than that of the formation of calcarious bodies; and may now distinguish four and even five epochs of the remotest antiquity: The first, when the matter of the globe was in fusion by fire, when the earth assumed its form, and the Equator was elevated and the Poles depressed by its rotatory motion: The second, when this matter consolidated, and formed the great masses of vitriifiable substances: The third, when the sea covered the whole land now inhabited, and nourished shell-animals, the remains of which have formed calcarious bodies: The fourth, when the waters which cover our Continents retired to their proper basins: A fifth epoch, the indications of which are equally clear as the other four, is the time when the elephant, the hippopotamus, and other southern animals, inhabited the regions of the north. This epoch is evidently posterior to the fourth, since the relicks of terrestrial animals are found near the surface of the earth, whilst those of marine animals are generally, and even in the same places, buried at great depths.

What, Will any man maintain, that elephants, and other animals now peculiar to the south, have formerly inhabited the regions of the north? This fact, however singular and extraordinary it may appear, is not the less certain. Great quantities of ivory have been and
daily

daily are found in Siberia, in Russia, and in other northern countries of Europe and Asia. These tusks of the elephant are found some feet below the earth, or they are exposed by the waters when they break down the banks of rivers. We find these tusks and bones of the elephant in so many places, and in such quantities, that they never could be brought into such cold regions by human power. From incontestible and reiterated proofs, we are obliged to acknowledge, that these animals were formerly natives of the north, as they are now of the south. What renders this fact more marvellous and more difficult to explain, we find the remains of those animals, now peculiar to the south of the Old Continent, not only in our northern provinces, but likewise in Canada and other parts of North America. In the Royal cabinet there are several tusks and many bones of the elephant, which were found in Siberia. We have other tusks and bones of the same animal which were found in France; as well as teeth of the hippopotamus discovered in America, near the river Ohio. Hence these animals, which cannot subsist in cold countries, have formerly existed in northern climates. Of course, the Frozen Zone was at that period equally warm as our Torrid Zone is at present; for it is impossible that the bodily constitution and real habits of these animals, which are the most permanent and invariable things in nature, should so far change

as to bestow the temperature of the rain-deer upon the elephant. Neither can we suppose that these southern animals, which require much heat for their subsistence, could ever live and multiply in northern regions, if the climate were equally cold as it is at present. M. Gmelin, who travelled in Siberia, and there collected many bones of the elephant, supposes that vast inundations in the south had driven the elephants to the north, where they would all perish at once by the rigour of the climate. But this cause is not proportioned to the effect. More ivory, perhaps, has already been brought from the north than all the elephants of India now existing could furnish. Much more will be discovered when the vast deserts of the north, which are scarcely known, shall be peopled, and the earth cultivated and dug by the hands of man. Besides, it is extremely improbable, that these animals should take the route which is most repugnant to their nature; for, if they were pushed by inundations from the south, why did they not rather fly to the east and west? Why did they fly as far as the sixtieth degree of north latitude, when they might have stopt on the road, or turned aside to more fortunate climates? And how is it possible to conceive, that, by an inundation from the southern ocean, the elephants were chased a thousand leagues into the Old Continent, and more than three thousand into the New? It is impossible that an inundation from the Indian ocean should drive the elephants

elephants into Canada, or even into Siberia; and it is equally impossible, that they should arrive in such numbers as are indicated by their remains.

Dissatisfied with this explication, I imagined that a more plausible one might be given, and which should perfectly correspond with my theory of the earth. But, before exhibiting my ideas on this subject, I shall, to prevent mistakes, remark, 1. That the ivory found in Siberia and in Canada unquestionably belongs to the elephant, and not to the morse or sea-cow, as some voyagers have pretended. In the northern regions, we likewise find the fossil ivory of the morse; but it is different from that of the elephant; and they are easily distinguished by comparing their internal texture. The tusks, the grinders, the scapulae, the thigh-bones, and other bones found in the northern climates, certainly belong to the elephant; it is even impossible to hesitate concerning the identity of the species. The large square teeth discovered in the same northern countries, the grinding side of which resembles the spade painted on cards, have every mark of the *dentes molares* of the hippopotamus; and those enormous teeth, the grinding side of which is composed of large blunt points or protuberances, have belonged to some terrestrial animal that now no longer exists, like the great volutes called *cornua ammonis*, which at present exist not in the ocean.

2. The

2. The bones and tusks of these ancient elephants are every way as large as those of the Indian elephants, to which we have compared them. This is a proof that these animals did not inhabit the northern regions from any necessity, since they acquired, in that situation, their full growth and complete dimensions. Of this fact we may be ascertained by the descriptions and dimensions of them given by M. Daubenton under the article *Elephant*. But, since that time, I have had transmitted to me an entire tusk and some fragments of fossil ivory, the length and breadth of which greatly exceed the tusks of the common elephant. I searched all the shops of the Paris ivory-merchants; but I found no tusk which could be compared to that in my possession. But, of a great number, I found only one equal to those sent from Siberia, whose circumference at the base is nineteen inches. Ivory, which is taken from living elephants, or from recent skeletons found in the forests, is denominated *raw ivory*; and the appellation of *roasted ivory* is given to that extracted from the earth, the quality of which is more or less altered, according to the time it has remained under ground, or according to the quality of the earth in which it has been buried. Most tusks which come from the North are still very solid, and very fine works may be made of them. The largest were sent to us by M. de L'Isle, an astronomer, and member of the Royal Academy
of

of Sciences. He collected them in his travels through Siberia. In all the shops of Paris, there was not a single tusk of raw ivory which measured nineteen inches in circumference: They were all smaller. This tusk was six feet and an inch in length; and it appears, that those in the Royal Cabinet, which were found in Siberia, were, when entire, more than six feet and a half: But, as their extremities were cut off, we could only make a near guess at their real length.

If we compare the thigh-bones found in the same northern countries, we shall be satisfied that they are at least equally long, and considerably thicker, than those of the Indian elephants.

Besides, as formerly remarked, we have made an exact comparison of the bones and tusks sent from Siberia with those of the skeleton of an elephant, and we found that all these bones are evidently the relicks of these animals. The Siberian tusks have not only the figure, but the genuine structure of elephant ivory, which M. Daubenton describes in the following terms.

‘ When an elephant’s tusk is cut transversely,
 ‘ we see, at or near the centre, a black point cal-
 ‘ led the *heart*. But, if the tusk is cut where it
 ‘ is hollow, there is only a round hole in the
 ‘ centre. We perceive crooked lines which ex-
 ‘ tend in different directions from the centre to
 ‘ the circumference, and, by crossing, form small
 ‘ lozenges. At the circumference, there is com-
 ‘ monly a narrow circular band. The crooked
 ‘ lines

* lines ramify in proportion as they recede from
 * the centre. Hence the size of the lozenges is
 * nearly the same throughout. Their sides, or at
 * least their angles, are of a more lively colour
 * than the areas, doubtless because their substance
 * is more compact. The band at the circum-
 * ference is composed of straight and transverse
 * fibres, which, if prolonged, would terminate in
 * the centre. It is the appearance of these lines
 * and points which is considered as the grain of
 * the ivory. This grain is perceptible in all ivories;
 * but it is more or less distinct in different tusks;
 * and, when the grain is sufficiently apparent, the
 * ivory gets the name of *large grained*, to distin-
 * guish it from that whose grain is fine.

It cannot be supposed that elephants could be
 transported into Siberia by men; for the state of
 captivity alone, independent of the rigour of the
 climate, would have reduced them to a fourth
 or a third of the dimensions which their remains
 exhibit. Of this effect we have sufficient proof
 from the comparison we have made between an
 entire skeleton of an elephant in the Royal Ca-
 binet, which had lived sixteen years at Versailles,
 with the tusks of other elephants brought from
 their native country. This skeleton and these
 tusks, though of considerable size, are one half
 smaller than the tusks and skeletons of these
 which live in freedom in Asia or in Africa; and,
 at the same time, they are at least two thirds
 smaller

smaller than the bones of the same animals found in Siberia.

3. The great quantities of ivory already discovered by accident in countries nearly desert, and where no man searches for it, show, that it is neither by one nor by several accidents, nor at one and the same time, that some individuals of this species have found their way into the northern regions, but that the species had formerly existed and multiplied there, in the same manner as they now exist and multiply in southern latitudes.

The only question, therefore, which remains to be solved, is, Whether there is or has been a cause that could so change the temperature of the different parts of the globe as to render the northern regions, which are now extremely cold, equally warm as the southern climates?

Some philosophers may imagine that this effect has been produced by the change in the obliquity of the ecliptic; because, at first sight, this change seems to indicate, that, as the inclination of the axis of the globe is not permanent, the earth might formerly revolve round an axis so different from that on which it now turns, as to make Siberia then lie immediately under the Equator. Astronomers have observed, that the change in the obliquity of the ecliptic is about 45 seconds in a century. Hence, by supposing this augmentation to be constant and successive, 60 centuries would produce a distance of 45 minutes,

minutes, and 3600 centuries would produce a change of 45 degrees. Such an alteration would bring back the 60th degree of latitude to the 15th, *i. e.* the country of Siberia, where the elephants formerly existed, to the regions of India, where they still exist and multiply. Now, it may be said, we have only to admit this long lapse of time in order to account for the regular abode of elephants in Siberia : It is 360,000 years ago since the earth revolved round an axis 45 degrees distant from that upon which it turns at present : The 15th degree of latitude was then the 60th, &c.

I answer, that this idea, and the mode of explication which results from it, cannot, upon examination, be supported. The change in the obliquity of the ecliptic is not a constant and successive diminution and augmentation. On the contrary, it is a limited variation, and sometimes on one side and sometimes on the other ; and, consequently, can never produce, on any side, nor in any climate, this difference of 45 degrees of inclination ; for the variation in the obliquity of the earth's axis is occasioned by the action of the planets, which alter the situation of the ecliptic, without affecting the equator. To take the strongest of these attractions, which is that of Venus, it would require 126,000 years to make a change of 180 degrees in the ecliptic of that planet, and, of course, to produce an alteration of 6 degrees 47 minutes
in

in the real obliquity of the earth's axis ; since 6 degrees 47 minutes are the double of the inclination of the orbit of Venus. In the same manner, the action of Jupiter cannot, in 93,6000 years, change the obliquity of the ecliptic above 2 degrees 38 minutes ; and still this effect is in part compensated by the preceding. Hence it is impossible that this change in the obliquity of the earth's axis should ever amount to 6 degrees, unless we suppose, that the orbits of all the planets should likewise change ; a supposition which we cannot nor ought not to admit, since no cause exists which could produce this effect.

But I am enabled to solve this difficult matter, and to deduce it from an immediate cause. We have already seen, that the terrestrial globe, when it first assumed its form, was in a state of fluidity, and that the water being unable to dissolve terrestrial bodies, this fluidity was a liquefaction occasioned by fire. Now, to pass from this burning and liquified state to a mild and temperate heat, time was necessary. The globe could not at once cool to its present temperature. Thus, during the first ages after its formation, the heat proper to the earth was infinitely greater than that which it received from the sun ; since it is still much greater. This immense fire being afterwards gradually dissipated, the polar, like all other climates, underwent successive changes from heat to cold.

Of

Of course, a certain time, or rather a long tract of time, existed, during which the northern regions, after having burnt like all others, enjoyed the same heat which at present is felt in the southern climates. Hence these northern countries might and actually have been inhabited by animals now peculiar to the south, and to whom this degree of heat is indispensable. The fact, therefore, instead of being extraordinary, perfectly accords with the other facts, and is no more than a consequence of them. Instead of opposing my theory of the earth, this fact, on the contrary, is an accessory proof of its reality, and confirms the most obscure point I have advanced ; i. e. when we attempt to look back into that profundity of time when the light of genius is apt to extinguish itself, and when, for want of observations, genius has no aid to lead us to a more remote period.

A sixth epoch, posterior to the other five, is that when the two Continents were separated from each other. It is certain, that they were not separated when the elephants lived equally in the north of Europe, Asia, and America ; I say, equally ; for we find their bones in Siberia, in Russia, and in Canada. Hence the separation of the two Continents happened posterior to the abode of these animals in the northern regions. But, as we likewise find the
tusks

tusks of the elephant in Poland, in Germany, in France, and in Italy, we must conclude, that, in proportion as these northern regions cooled, the elephants retired toward the temperate zone, where the heat of the sun, and the greater thickness of the globe, compensated the loss of the earth's internal heat; and that, in the progress of time, the temperate zone having also become too cold, the elephant gradually migrated to the climates under the Torrid Zone, which alone have longest preserved, by the greater thickness of the globe, a superior degree of internal heat. These are likewise the only climates where this interior heat, united with that of the sun, is still sufficient to support their existence, and to permit them to propagate their species.

Independent of the specimens transmitted from Russia and Siberia, and which are preserved in the Royal cabinet, there are many others in private collections. Vast numbers of them are to be seen in the museum of Petersburg, as appears from a catalogue printed in the year 1742. There are likewise many of them in the British museum, in that of Copenhagen, and in some other collections in Britain, Germany, and Italy. This northern ivory, like the southern, is used in manufacturing many articles of hardware, &c. Hence the great quantity of the tusks and bones of elephants found in Siberia

ria and Russia can no longer remain a doubtful point.

M. Pallas, a learned naturalist, in his late journey through Siberia, found a great quantity of elephants bones, and an entire skeleton of a rhinoceros, which was buried a few feet only under the surface of the ground.

‘ Enormous bones of the elephant were lately discovered at Swijatoki, seventeen versts from Petersburg: They were found in a spot which had long been covered with water. Hence some prodigious revolution must have changed the climate, the productions, and the animals, in every quarter of the globe. These medals of Nature prove, that those countries which are now desolated by the rigours of intense cold, have formerly enjoyed all the advantages of the southern latitudes *.’

The discovery of the tusks and skeletons of elephants in Canada is but recent; and I was first informed of them by a letter from the late Mr Collison, fellow of the Royal Society of London, of which the following is a translation.

‘ Mr George Croghan has assured me, that, in the course of his travels through the countries bordering upon the river Ohio, in the year 1765 and 1766, about four miles south-east

* Journal de Politique et de Literature, 5. Jan. 1776, art. *Peterbourg.*

‘ east from this river, and 640 miles distant
 ‘ from Fort du Quesne or Pittsburgh, he saw, in
 ‘ the neighbourhood of a large salt marsh, where
 ‘ the wild animals assemble at certain seasons of
 ‘ the year, immense bones and teeth. Having
 ‘ carefully examined the place, he discovered,
 ‘ in a high bank on the side of the marsh, a
 ‘ prodigious number of bones, which, from
 ‘ their figure and magnitude, appeared to be
 ‘ the bones and tusks of elephants.

‘ But, Sir, the large grinding teeth which I
 ‘ send you, were found along with these tusks.
 ‘ There are others still larger than these, which
 ‘ seem to indicate, and even to demonstrate,
 ‘ that they belong not to elephants. How shall
 ‘ we reconcile this paradox? May we not sup-
 ‘ pose, that there formerly existed a large ani-
 ‘ mal which had the tusks of an elephant and
 ‘ the grinders of the hippopotamus? for these
 ‘ large grinders are very different from those of
 ‘ the elephant. From the great number of tusks
 ‘ and grinders which he saw, Mr Croghan thinks,
 ‘ that there must have been at least thirty of
 ‘ these animals buried in this place. Elephants,
 ‘ however, were never known in America; and
 ‘ it is improbable that they could be brought
 ‘ there from Asia. The impossibility of their li-
 ‘ ving in countries where the winters are so ri-
 ‘ gorous, but where great quantities of their
 VOL. IX. T bones

‘ bones are found, makes a paradox, which
 ‘ your great sagacity may perhaps explain.

‘ Mr Croghan, in the month of February
 ‘ 1767, sent to different persons in London, the
 ‘ bones and teeth he had collected in the years
 ‘ 1765 and 1766.

‘ 1. To my Lord Shelburn, two large tusks,
 ‘ one of which was entire, and near seven feet
 ‘ long: Its thickness exceeded not that of a com-
 ‘ mon tusk of an elephant of an equal length.

‘ 2. A jaw-bone with two grinders in it, be-
 ‘ side several enormous separate grinders.

‘ To Dr Franklin, 1. Three tusks, one of
 ‘ which was about six feet long. It had been
 ‘ broke through the middle, which was corrupt-
 ‘ ed, and resembled chalk. The others were
 ‘ sound. The end of one of them was sharpen-
 ‘ ed to a point, and it consisted of very fine i-
 ‘ vory.

‘ 2. A small tusk, about three feet long, and
 ‘ as thick as a man’s arm, with the depressions
 ‘ made by the muscles and tendons, which were
 ‘ of a bright chesnut colour, and appeared to be
 ‘ as fresh as if recently taken from the head of
 ‘ the animal.

‘ 3. Four grinders, one of the largest of
 ‘ which was broader than those I sent you, and
 ‘ had likewise an additional row of knobs. All
 ‘ those presented to my Lord Shelburn and Dr
 ‘ Franklin were of the same form, and had the
 ‘ same

' same enamel, as the specimens I now transmit
' for your examination.

' Dr Franklin lately dined with an officer, who
' had brought from the same place, in the neigh-
' bourhood of the river Ohio, a tusk which was
' whiter, more lustrous, and more entire than
' any of the others ; and likewise a grinder still
' larger than any of those I have mentioned *.'

*Extract from a Journal of a voyage made by Mr
Crogan on the river Ohio, and transmitted to
Dr Franklin in the month of May 1765.*

' Having passed the great river Miame, we
' arrived, in the evening, at the place where the
' bones of elephants are found. It is about 640
' miles from Fort Pitt. In the morning, I
' went to the large marsh where the wild ani-
' mals assemble at certain times of the year.
' We came to this place by a road beaten with
' the feet of the wild oxen, or bisons. It is a-
' bout four miles south-east from the river Ohio.
' We saw a great number of bones, some of
' them scattered about, and others buried five or
' six feet below the surface. We saw them in a
' bank of earth along the side of the road. We
' found two tusks of six feet in length, which
' we carried to our hut, along with other bones
' and teeth. The following year we returned

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' to

* Lettre Mr Collinson to M. de Buffon, dated Mill-hill,
near London, July 3. 1767.

'to the same place, in order to procure a great-
 'er number of tusks and teeth.
 'If M. de Buffon had any queries to make
 'upon this subject, I entreated him, says Mr
 Collinson, 'to transmit them to me; I shall send
 'them to Mr Croghan, a man of integrity and
 'parts, who will be happy to answer every
 'question.' This little Memoir was subjoined
 to the letter which I have just now quoted, and
 to which I shall add an extract of what Mr Col-
 linson formerly wrote me concerning these A-
 merican bones.

'About a mile and a half from the river Ohio,
 'there are six enormous skeletons buried on end,
 'with tusks from five to six feet long, and of
 'the same form and substance as elephants tusks.
 'They were thirty inches in circumference at
 'the root. They tapered to a point. But, as they
 'were broken, we could not perceive how they
 'were joined to the jaws. A thigh-bone of the
 'same animals was found entire. It weighed a
 'hundred pounds, and was four and a half feet
 'in length. These tusks and thigh-bones show
 'that the animal must have been of a prodigious
 'magnitude. These facts have been confirmed
 'by Mr Greenwood, who saw the six skeletons
 'in the salt-marsh. In the same place, he like-
 'wise found large grinders, which appeared not
 'to belong to the elephant, but rather to the
 'hippopotamus. Some of these teeth he sent to
 'London,

' London, among others, two of which together
 ' weighed $9\frac{1}{4}$ pounds. He says, that the jaw-
 ' bone was too heavy to be carried by two men.
 ' The interval between the orbits of the two
 ' eyes was eighteen inches. An Englishman,
 ' who had been taken prisoner by the savages,
 ' and conducted to this salt-marsh in order to
 ' teach them how to make salt by evaporating
 ' the water, declared, that, from a peculiar cir-
 ' cumstance, he remembered to have seen these
 ' enormous bones. He told, that three French-
 ' men, who were breaking nuts, sat upon a single
 ' thigh-bone.'

Some time after writing these letters, Mr
 Collinson read to the Royal Society of London
 two short essays on the same subject, in which I
 found some new facts, which I shall relate, and
 add elucidations of such things as may require
 explanation.

' The salt-marsh where the elephants bones
 ' are found is about four miles distant from the
 ' banks of the river Ohio; but it is more than
 ' seven hundred miles from the nearest coast of
 ' the sea. There is a road beaten by the wild
 ' oxen, or bisons, large enough to allow two
 ' chariots to travel abreast. This road directly
 ' leads to the great salt-marsh where these ani-
 ' mals, as well as stags and other species of the
 ' deer, assemble at a certain season of the year
 ' to lick the earth and drink the salt water. . . .

' The elephants bones are found in a bank of
 ' about six or seven feet high, which surrounds
 ' the marsh. There we see teeth and bones
 ' which had formerly belonged to some animals
 ' of a prodigious size. Some of the tusks are
 ' near seven feet in length, and consist of excel-
 ' lent ivory; and therefore we cannot entertain
 ' any doubt that they really belong to the ele-
 ' phant species. It is singular, however, that,
 ' among these tusks, we never meet with a sin-
 ' gle grinder of an elephant, but a vast number
 ' of enormous teeth, each of which has five or
 ' six blunt knobs, and must have belonged to
 ' some animal of an immense size. These square
 ' teeth have no resemblance to the grinders of
 ' the elephant, which are flat, and four or five
 ' times broader than thick; so that these e-
 ' normous grinders have no resemblance to the
 ' teeth of any known animal.'

' This last remark of Mr Collinson is extremely
 just: These large grinders are totally different
 from those of the elephant; and, by comparing
 them with the grinders of the hippopotamus,
 which they resemble by their square figure, we
 shall perceive that they likewise differ in size,
 as they are two, three, and even four times
 more voluminous than the largest teeth of the
 ancient hippopotami found in Siberia and Ca-
 nada, though these last teeth are three or four
 times larger than those of the hippopotami
 which

which now exist. All the teeth which I have examined in four heads of these animals preserved in the Royal Cabinet, have the grinding side hollowed in the form of a card-spade, and those found in Canada and Siberia have the same character, and differ from them in size only. But those enormous teeth with large blunt knobs have always four and sometimes five rows; whilst the largest teeth of the hippopotamus have only three, as may be seen by comparing the figures of plate CII. CIV. and CV. with those of plate CVI. It seems, therefore, to be certain, that these large teeth have never belonged either to the elephant or to the hippopotamus: The difference in size, though enormous, would not prevent us from regarding them as pertaining to this last species, if all the characters in their form were the same; since we know, as formerly remarked, other square teeth three or four times larger than those of the present existing hippopotami, and which, having the precise same characters, are unquestionably the teeth of hippopotami that have been three times larger than those whose heads are in the Royal Cabinet. I meant those large teeth, which really belong to the hippopotamus, when I remarked, that they were equally found in both Continents, as well as the tusks of the elephant. It is remarkable, however, that we not only find real tusks of the elephant, and real teeth of
the

the large hippopotamus, in Siberia and Canada, but we likewise find in the same countries those enormous teeth with four rows of large blunt knobs. We may, therefore, conclude, that this immense animal no longer exists, and that the species is entirely extinct.

M. le Comte de Vergennes, minister and secretary of state, was so obliging as to give me, in the year 1770, the largest of all these teeth, which is represented in plates CII. and CIII.; it weighed eleven pounds four ounces. This immense tooth was discovered in making a ditch in Little Tartary. There were other bones which could not be collected, and, among these, a thigh-bone, of which one half only was entire, and the cavity of this half contained fifteen Paris pints of water. M. l'Abbé Chappe, of the Academy of sciences, brought me from Siberia a similar tooth, but smaller, and which weighed only three pounds twelve and a half ounces. (Plate CIV. fig. 1. and 2.) Lastly, the largest of those transmitted to me by Mr Collinson, and which is represented, (plate CV.) was found, among several others, near the river Ohio in America; and they perfectly resemble other specimens brought from Canada.

From all these facts it is apparent, that, independent of the elephant and hippopotamus, whose relicks are equally found in the two continents, another animal common to both has
formerly

formerly existed, the size of which has greatly exceeded that of the largest elephants; for the square form of these enormous grinders shows, that they were numerous in each jaw; and supposing there were only six or even four in each side of the jaws, we may form some notion of the magnitude of a head which could contain sixteen grinders, each weighing ten or eleven pounds. The elephant has only four grinders, two on each side. They are flat, and occupy the whole jaw; and these two flat grinders of the elephant surpass by two inches only the breadth of the largest square tooth of the unknown animal, which is double the thickness of those of the elephant. Thus every circumstance leads us to think, that this ancient species, which ought to be regarded as the largest of all terrestrial animals, existed during the first ages only; for an animal much larger than the elephant could not be so concealed in any part of the earth as to remain perfectly unknown. Besides, it is evident, from the figure of these teeth, as well as from the enamel, and the disposition of their roots, that they have no relation to the teeth of the cetaceous tribes; and that they have really belonged to a land-animal whose species made a nearer approach to that of the hippopotamus than to any other.

In the course of his essay, Mr Collinson informs us, that several members of the Royal Society

Society were equally well acquainted with the elephants tusks daily found in Siberia, upon the banks of the Oby, and other rivers of that country. What system, he adds, can be formed, which will, with any degree of probability, account for those bones of the elephant found in Siberia and in America? He concludes with enumerating the weight and dimensions of all the teeth brought from the salt-marsh near the river Ohio, the largest of which belonged to Captain Ourry, and weighed six pounds and a half.

Mr Collinson, in his second essay, read before the Royal Society of London December 10. 1767, remarks, that, as one of the tusks found in the salt-marsh was striated or furrowed near the thickest end, he entertained some doubts whether these furrows were peculiar to the elephant species. To satisfy himself on this head, he visited the warehouse of a merchant who dealt in all kinds of teeth; and, after examining them, he discovered that there were as many tusks furrowed as smooth at the thick end; and, of course, he had no difficulty in pronouncing, that the tusks found in America were, in every respect, similar to those of the African and Asiatic elephants. But, as the large American square teeth have no relation to the grinders of the elephant, he thinks, that they are the remains of some enormous animal which had tusks like an elephant, and grinders peculiar to its own species, their
magnitude

magnitude and form being totally different from those of any known animal*.

In the year 1748, M. Fabri, who had made great excursions into the northern parts of Louisiana and the southern regions of Canada, informed me, that he had seen heads and skeletons of an enormous quadruped, called by the Savages the *father of Oxen*; and that the thigh-bones of these animals were from five to six feet in length. Some time after, and previous to the year 1767 specimens of these large teeth belonging to the unknown animal, as well as those of the hippopotamus, and bones of the elephant, all found in America, were transmitted to Paris. The number of them is too considerable to leave any doubt that these animals formerly existed in the northern regions of America, as well as in those of Europe and Asia.

But elephants have likewise existed in all the temperate countries of our Continent. I mentioned tusks found in Languedoc near Simore, and those discovered in Cominges in Gascony. To these I shall add the largest and finest of the whole, lately sent to the Royal Cabinet by the Duc de la Rochefoucauld, whose zeal for promoting science is a result of his general knowledge. This excellent specimen he found, along with M. Desmarets of the Academy of Sciences,

* Phil. Transf. 1767.

ences, when viewing the fields in the environs of Rome. This tusk was divided into five fragments, which the Duc de la Rochefoucauld ordered to be collected. One of these fragments was stolen by the porter who had the charge of it, and there remained only four, which were about eight inches in diameter. When laid together, these four fragments were seven feet in length; and we learn from M. Desmarests, that the fifth fragment, which was lost, was near three feet long. Hence the total length of the tusk must have been about ten feet. By examining the broken ends, we discovered every character of elephantine ivory; though, by being long buried under ground, it has become light and friable, like all other fossil ivories.

M. Tozzetti, a learned Italian naturalist, relates, that there were found, in the valleys of Arno, the bones of elephants and other terrestrial animals in great quantities, scattered here and there in the strata of the earth. We may, therefore, he remarks, conclude, that elephants were formerly natives of Europe, and especially of Tuscany*.

‘We found,’ says M. Caliellini, ‘about the end of November 1759, in a country estate belonging to the Marquis de Petrella, situated at Fusigliano in the territory of Cortona, a
‘ fragment

* Extrait d'une lettre du Docteur Tozzetti, Journal étranger, mois de Decembre 1755.

' fragment of an elephant's bone mostly encrust-
' ed with a stony matter. Similar fossil
' bones have formerly been discovered in our
' environs:

' In the cabinet of M. Galeotto Corazzi, there
' is another large portion of a petrified elephant's
' tusk, which was lately found in the neighbour-
' hood of Cortona, at a place called *la Selva*.

' Having compared these fragments with a piece
' of an elephant's tusk lately brought from Asia,
' we found that the resemblance between them
' was perfect.

' In the month of April last, M. l'Abbé Mea-
' rini brought me an entire jaw-bone of an ele-
' phant, which he had found in the district of
' Farneta, a village belonging to this diocese.
' This jaw-bone is mostly petrified, and parti-
' cularly on the two sides, where the stony in-
' crustation rises an inch above the surface, and
' has all the hardness of a stone.

' Lastly, I am indebted to M. Muzio Angelieri
' Alticozzi, a gentleman of this town, for a
' thigh-bone of an elephant, which is almost
' entire. He discovered it in one of his country
' estates called *Rota*, which is situated in the
' territory of Cortona. This bone is a Florence
' fathom long, and is likewise petrified, particu-
' larly in the upper extremity, called the head*.

In

* Lettre de M. Louis Coltellini de Cortone ; Journal é-
tranger, mois de Juillet 1761.

In the same manner, we find in France, and in all the other nations of Europe, skeletons and vertebrae of marine animals, which can only subsist in the most southern seas. The same change of temperature, therefore, has happened in the various parts of the ocean as well as in those of the land; and this second fact, like the first, as it proceeds from the same cause, confirms the whole.

When we compare those ancient monuments of the first age of animated nature with her actual productions, we evidently perceive that the constituent form of each animal has remained the same, and that there is no alteration in the principal parts of their structure. The type of each species has suffered no change. The internal mould has invariably preserved its form. However long we may suppose the succession of time, whatever number of generations may have passed, the individuals of each kind still exhibit the same forms as those of the first ages, especially in the larger species, whose characters are more fixed, and whose nature is more permanent; for the inferior species have, as formerly remarked, been sensibly affected by the different causes of degeneration. We must, however, remark, with regard to the larger species, such as the elephant and hippopotamus, that, by comparing their ancient remains with those of our times, we, in general, perceive that these animals

nimals were then much larger than they are at present. Nature was then in her primitive vigour. The internal heat of the earth bestowed on its productions all the vigour and magnitude of which they were susceptible. The first ages produced giants of every kind. Dwarfs and pigmies succeeded, after the earth had cooled; and if, as other monuments seems to indicate, some species of animals, which formerly existed, are now lost, this effect could only be produced, because their nature required a greater degree of heat than what is now felt in the torrid zone. Those enormous and nearly square grinders with blunt knobs, those large *cornua ammonis*, of which some are several feet in diameter, and many other fossil fishes and shells, which no longer have any living representatives, existed only in those primitive times when the earth and sea were still warm, and produced and nourished animals to whom this degree of heat was necessary, and who exist not at present, because they have probably perished by cold.

To know all the petrifications of which there are no living representatives, would require long study and an exact comparison of the various species of petrified bodies, which have been found in the bowels of the earth. This science is still in its infancy. We are certain, however, that there are many of those species, such as, the *cornua ammonis*, *ortoceratites*, *lenticular*

ticular and numismal stones, belemnites, Judaic stones, anthropomorphites, &c. which cannot be referred to any species now existing. We have seen *cornua ammonis* of two and three feet in diameter; and we have been assured by men worthy of credit, that a *cornua ammonis* has been found in Champagne larger than a mill-stone, since it was eight feet in diameter and one foot thick. I had an offer of its being sent to me. But the enormous weight of this mass, which is 8000 pounds, and its great distance from Paris, prevented me from accepting the present. These examples, and others which might be given, are sufficient to show, that many species of shell and crustaceous animals formerly existed in the sea, of which there are now no living representatives. The same observation is applicable to some of the scaly fishes. Most of those found in certain slates have so little resemblance to the fishes with which we are acquainted, that their species cannot be ascertained. Even those in the Royal Cabinet, which are perfectly preserved in masses of stone, cannot be referred to any of our known species. It appears, therefore, that the sea formerly nourished many genera, whose species no longer exist.

But, with regard to terrestrial animals, we have only a single example of a lost species, and it appears to have been the largest, without excepting even the elephant: And, since the
examples

examples of lost species are more rare in land than in marine animals, is it not probable, that the production of the former was posterior to that of the latter?

From these facts and monuments we may perceive six successive epochs in the first ages of Nature; six species of duration, the limits of which, though indeterminate, are not the less real; for these epochs are not, like those of civil history, marked by fixed points, or limited by centuries and other portions of time which admit of an exact measurement. They may, however, be compared between themselves, and their relative duration may be estimated by other facts and monuments, which indicate contemporary dates.

* * * * *

After finishing his preliminary discourse, the Count de Buffon proceeds to state the different epochs of Nature, which he divides into seven great periods.

EPOCH FIRST.

When the Earth and Planets first assumed their proper Form.

VOL. IX.

U

EPOCH

EPOCH SECOND.

When the fluid matter consolidated, and formed the interior rock of the globe, as well as those great vitrifiable masses which appear on its surface.

EPOCH THIRD.

When the waters covered all the Continents.

EPOCH FOURTH.

When the waters retired, and Volcano's began to act.

EPOCH FIFTH.

When the elephants, and other animals of the south, inhabited the northern regions.

EPOCH SIXTH.

When the Continents were separated from each other.

EPOCH SEVENTH, and last.

When the power of Man assisted the operations of Nature.

These

These epochs are purely hypothetical, and depend more or less on the notion, that the earth and planets were originally driven from the body of the sun by the impulse of a comet, and, of course, remained long in a state of liquid fire. We shall therefore content ourselves with having barely mentioned them, and proceed to enumerate some facts and positions, which, though applied in support of a fanciful system, are curious, and may be useful.

The Count de Buffon remarks, that the cavities and eminences of the globe have been encrusted, and sometimes filled with metallic substances, which are still found in these situations.

‘Metallic veins,’ says M. Eller, ‘are found only in elevated places, in a long chain of mountains. This chain of mountains is always supported by a basis of hard rock. As long as this rock preserves its continuity, there is no chance of discovering metallic veins. But, when we meet with crevices or fissures, we then entertain hopes of finding metal. Mineralogists have remarked, that, in Germany, the most favourable situation is when the mountains rise gradually, stretch toward the south-east, and, after attaining their greatest elevation, descend gently toward the north west. . . .’

'It is generally in a rugged rock, the extent
'of which is often unlimited, but split into

' fissures, that metals are found sometimes pure,
 ' but generally in the state of ores. These fis-
 ' sures are commonly encrusted with a white
 ' shining substance called *quartz* by the miners:
 ' When heavier, but soft and laminated nearly
 ' like chalk, it receives the denomination of
 ' *spar*. It is surrounded, on the side next the
 ' rock, with a kind of slime, which seems to
 ' nourish these quartzzy or sparry earths. These
 ' two coverings serve as a sheath for the vein.
 ' The more perpendicular the vein, the more is
 ' to be expected from it. Whenever the miners
 ' find a perpendicular vein, they say that it
 ' will be very productive.
 ' In these fissures and cavities, metals are form-
 ' ed by a perpetual and pretty strong evaporation.
 ' The vapours which issue from mines show
 ' that this evaporation is still going on. Fissures
 ' which have no exhalation are commonly bar-
 ' ren of metal. The most certain proof that the
 ' exhaling vapours carry along with them mi-
 ' neral particles, and apply them to the sides of
 ' the fissures, is that successive encrustation which
 ' is apparent in the whole circumference of
 ' these fissures or hollows of rocks, till their ca-
 ' vities are completely filled, and the solid vein
 ' is formed. This fact is still farther confirmed
 ' by the tools left in these hollows; and, several
 ' years after, they are found to be encrusted
 ' with metal.

' The

‘ The fissures which furnish the most rich
 ‘ veins of metal always incline to a perpendicular
 ‘ direction. In proportion as the miners de-
 ‘ scend, the temperature of the air is always
 ‘ warmer; and the exhalations are sometimes so
 ‘ abundant, and so noxious, that, in order to
 ‘ avoid suffocation, the miners are obliged to
 ‘ fly to the pits or galleries, otherwise they
 ‘ would be instantly destroyed by the arsenical
 ‘ and sulphureous particles. Sulphur and arsenic
 ‘ are commonly found in the four imperfect,
 ‘ and in all the semimetals, and it is from these
 ‘ they receive their metallic form.

‘ Gold, and sometimes silver and copper, are
 ‘ the only metals which are found pure in any
 ‘ quantities. But, in general, copper, iron,
 ‘ lead, and tin, when taken out of the veins,
 ‘ are mineralized with sulphur and arsenic. We
 ‘ know from experience, that metals lose their
 ‘ metallic form by degrees of heat proportioned
 ‘ to each species. This destruction of the metal-
 ‘ lic form, which the four imperfect metals under-
 ‘ go, shows that the basis of metals is an ear-
 ‘ thy matter; and, as these calces, as well as the
 ‘ calcarious and gypseous earths, vitrify by the
 ‘ application of a certain degree of heat, we
 ‘ are certain that metallic earth belongs to the
 ‘ class of vitrifiable earths *.

U 3

M.

* Mem. de M. Eller sur l'origine et la generation des Me-
 taux.

M. Lehman, a celebrated chymist, is the first person who suspected that metallic substances had a double origin. 'Gold and silver,' he remarks, 'are found in masses only in the mountains which have veins, and iron is found only in those mountains which have regular strata. All the small pieces of gold and silver found in the mountains with strata have been detached from veins in the superior mountains in the neighbourhood of the former.'

'Gold is never in the form of ore. It is always found in a native or virgin state, though it is often scattered about in particles so minute, that it cannot be distinguished even by the best microscopes. In the mountains with strata, no gold, and very little silver, are to be found. These two metals belong exclusively to mountains with veins. Sometimes, however, we find silver in small leaves, or under the form of hair, in slate. Native copper oftener occurs in slate; and this copper is also commonly in the form of threads or hair.'

'A few years after iron-ores have been taken from the earth, they are reproduced. They are not found in the mountains with veins, but in those with strata. Iron is seldom, if ever, met with in a native state.'

'With regard to native tin, it has no existence in Nature, and is only produced by the assistance of fire. The same remark is applicable
cable

' cable to lead, though the grains found in Sile-
' sia have been considered as native lead.

' Native mercury is found in strata of fat ar-
' gillaceous earth, or in slate.

' The silver ores found in slate are not nearly
' so rich as those found in the mountains with
' veins. This metal is found in beds of slate;
' and is always in the form of minute particles,
' threads, or ramifications, but never appears in
' large masses. These beds of slate must like-
' wise be adjacent to the mountains with veins.
' The silver-ores found in strata are never in a
' solid or compact form. All the other ores,
' which contain much silver, are peculiar to the
' mountains with veins. There is a great deal
' of silver in the strata of slate; and it is also
' sometimes found in pit-coal.

' Tin is the metal which most rarely appears
' in strata; lead is more common in that situa-
' tion. We find it attached to slate, but never
' to coal.

' Iron is almost universally diffused, and is
' found in beds under a number of different
' forms.

' Cinnabar, cobalt, bismuth, and lapis cala-
' minaris, are likewise commonly found in beds.

' Pit-coal, jett, amber, and aluminous earth,
' are produced by vegetables, and especially by
' resinous trees which have been buried in the
' earth, and have been more or less decom-
' posed;

‘ posed ; for we often find, above the strata of
 ‘ coal, wood which is not totally decomposed ; and
 ‘ it is still more decomposed as we descend deeper. Slate, which covers coal, is often full of the
 ‘ impressions of plants, such as ferns, maiden-
 ‘ hair, &c. It is remarkable, that all these im-
 ‘ pressions belong to foreign plants, and the wood
 ‘ likewise appears to be foreign. Amber, which
 ‘ ought to be regarded as a vegetable resin, often
 ‘ includes insects, which, when attentively ex-
 ‘ amined, belong not to the climate where they
 ‘ now exist. Aluminous earth is frequently la-
 ‘ minated, and resembles wood sometimes more
 ‘ and sometimes less decomposed.

‘ Sulphur, alum, and sal ammoniac, are found
 ‘ in beds formed by volcano’s.

‘ Petroleum and naphtha indicate a subterra-
 ‘ neous fire, which produces a distillation from
 ‘ pit-coal. We have examples of these subter-
 ‘ raneous fires which act silently, in the coal
 ‘ strata of Britain and Germany. They burn
 ‘ long without any explosion ; and it is in the
 ‘ neighbourhood of these subterraneous fires
 ‘ that hot springs are found.

‘ The mountains which contain veins include
 ‘ neither coal nor bituminous and combustible
 ‘ bodies: These substances are found only in the
 ‘ mountains with strata.’

In the second epoch of Nature, the Count
 de Buffon remarks, ‘ that, in the northern re-
 ‘ gions

regions there are mountains composed entirely of iron.' I mention, says he, by way of example, the iron mines near Taberg in Smoland, a part of the island of Gothland in Sweden. It is the most remarkable of those mines, or rather mountains of iron which have the quality of yielding to the attraction of the load-stone; which proves that they have been formed by the action of fire. The basis of this mountain is a very fine sand. Its height is more than 400 feet, and its circumference about one league. It is composed entirely of a rich ferruginous matter, and we even find in it native iron; which is another proof that it has undergone the action of a violent fire. This ore, when broken, exhibits small shining particles, which sometimes cross each other, and sometimes are arranged like scales. This mine has been wrought above two hundred years.

The ore in this mountain is not disposed in regular beds; neither is the iron every where of equal goodness. Through the whole mountain there are fissures sometimes perpendicular, and sometimes horizontal: These are all filled with sand, which contains no iron. This sand is pure, and of the same species with that on the sea-coast. In this sand, we sometimes find the bones of animals, and the horns of stags, which shows that the sand has been carried thither by the waters, and that the formation of this iron mountain

mountain by fire happened before the crevices and the perpendicular and horizontal fissures were filled with sand.

The masses of ore are rolled down from the top of the mountain; but, in other mines, the minerals must be drawn up from the bowels of the earth. This ore must be broken to pieces, or pounded, before it is put into the furnace, where it is smelted by means of charcoal and calcarious stones.

This hill of iron is situated in an elevated and mountainous district, about eighty leagues from the sea: It seems to have formerly been altogether covered with sand*.

We are next informed, that there are mountains of load-stone in some countries, and particularly in those of the North. From the foregoing example, we have seen that the iron mountain of Taberg rises 400 feet above the level of the sea. M. Gmelin, in his travels through Siberia, remarks, that, in the northern countries of Asia, almost all the metallic ores are found on the surface of the earth, whilst in other countries they are buried deep in the interior parts of the earth. This fact, if generally true, is a new proof that metals have been formed by the primitive fire, and that the globe be-
ing

* Extrait d'un article de l'ouvrage periodique qui a pour titre, *Norfdilche beytrage*, &c. Contribution du Nord pour les progrès de la physique, des Sciences, et des arts, 1756.

ing less thick in the northern regions, metals were formed nearer the surface than in the southern countries.

M. Gmelin examined the great mountain of loadstone among the Baschkires in Siberia. This mountain is divided into eight parts by valleys, of which the seventh part produces the best loadstone. The summit of this portion of the mountain consists of a yellowish stone, which seems to partake of the nature of jasper. We there find stones that have the appearance of free-stone, which weigh from two to three thousand pounds; but they all have a magnetic virtue. Though covered with moss, they fail not, at more than the distance of an inch, to attract iron and steel. The sides exposed to the air have the strongest magnetic power, those covered with the earth being much weaker. Those parts which are exposed to the injuries of the air are softer, and, consequently, less proper for being armed. A large portion of loadstone, of the size above mentioned, is composed of a number of other portions which act in different directions. To work them properly, they should be separated in such a manner that the whole portion, which includes the virtue of each particular magnet, should preserve its unity: By observing this rule, we would probably obtain magnets of an uncommon strength. But, as they are cut without any foresight, many portions

portions are of no value, either because they contain little no magnetic power, or because, in a single piece, there are two or three magnets united: Such portions have indeed a magnetic virtue; but, as it is not directed to the same point, a magnet of this kind must be subject to great variations.

The loadstone of this mountain, except what is exposed to the air, is exceedingly hard, spotted with black, and full of little knots or protuberances, consisting of small angular parts, like those often observable on the surface of bloodstone, from which it differs only in colour; but, instead of these angular parts, we sometimes perceive a kind of ochrey earth. In general, loadstones with these angular parts have less power than the other kinds. That part of the mountain where the loadstones are found is composed almost entirely of a fine iron ore, which lies in small portions among the loadstones. The whole section of the high part of the mountain contains a similar ore; but, in proportion as we descend, the metal is more rare. Below the ore of loadstone, there are other ferruginous stones, which, if melted, would produce very little iron. These stones have the colour of metal, and are very heavy. Their interior parts are irregular, and have nearly the appearance of scoriae. In their surfaces they pretty much resemble loadstones; but they have no magnetic

magnetic power. Between these stones there are other pieces of rock which appear to be composed of small particles of iron. The stone itself is heavy, but very soft. The interior parts resemble burned matter, and they have little or no magnetic virtue. We likewise meet occasionally with a brown iron ore in beds of an inch thick; but it yields very little metal*.

In the mountains of Poias in Siberia, there are several other mines of loadstone. Ten leagues off the road which leads from Catharinbourg to Salikamskaia, there is a hill called *Galazinski*, which is more than twenty fathoms high, and is entirely composed of a loadstone rock. It has the brown colour and the density of iron.

Twenty leagues from Salikamskaia, we find cubical loadstones of a brilliant greenish colour. When pulverised, the grains have the appearance of fire. It is worthy of remark, that loadstone is found only in those chains of mountains which stretch from south to north†.

In the countries bordering upon Lapland, and on the confines of Bothnia, two leagues distant from Cokluanda, there is an iron-ore, from which very fine loadstones are extracted. 'We 'admired,' says Regnard, 'the surprising effects of

* Extrait d'Hist. generale des voyages, tom. 18. p. 141. &c.

† Ibid. tom. 19. p. 472.

‘of this stone, when it remained in its natural
 ‘situation: It required a great deal of force to
 ‘obtain pieces of the magnitude we wished; and
 ‘the large hammer employed remained so fixed
 ‘to the wedge in the stone, that the workman
 ‘required assistance to disengage it. I tried the
 ‘experiment myself; I took a large iron lever,
 ‘which was so heavy that I could hardly sup-
 ‘port it; I brought it near the wedge by which
 ‘it was attracted and supported with an ama-
 ‘zing force. I held a mariner’s compass in the
 ‘middle of the hole where the ore lay, and the
 ‘needle revolved perpetually with an incredible
 ‘rapidity*.’

In Vol. I. p. 29. I remarked, ‘that, accor-
 ‘ding to the relation of voyagers, the mountains
 ‘of the north are but small hills, when compa-
 ‘red to the mountains of the equatorial regions;
 ‘and that the general movement of the waters
 ‘produced those large mountains in the Old
 ‘Continent, which stretch from east to west,
 ‘and from north to south in the New.’

This passage requires explanation, as well as
 some restrictions. From a thousand observa-
 tions, it is certain, that shells and other produc-
 tions of the ocean are found upon the whole
 surface of the inhabited parts of the earth, and
 even upon the mountains to a very great height.

I

* Oeuvres de Regnard, tom. 1. p. 185.

I advanced, from the authority of Woodward, who first collected facts upon this subject, that shells were likewise found on the tops of the highest mountains. From my own observations, as well as those of others, I know, that there are shells in the Alps and Pyrennees at 900, 1000, 1200, and 1500 fathoms above the level of the sea; that they are likewise found in the mountains of Asia; and, lastly, in the Cordilleres of America, a bank of shells has lately been discovered at the height of more than 2000 fathoms above the sea *.

It is, therefore, certain, that, in all the different parts of the world, and even to the height of 1500 or 2000 fathoms above the present level

* M. le Gentil, of the academy of Sciences, wrote me the following letter, in December 1771: 'Don Antonia Ulloa, desired me, when departing from Cadiz, to send him two petrified shells, which, in the year 1761, he had dug out of the mountain that contains the quick silver mines. This mountain is in the government of Quanca-Velica in Peru. Its southern latitude is from 13 to 14 degrees. At the place where these shells are found, the mercury stood at 17 inches $1\frac{1}{4}$ line, which corresponds to the height of 2222 $\frac{1}{2}$ fathoms above the level of the sea.

'At the top of the mountain, which is far from being the highest in this canton, the mercury stands at 16 $\frac{1}{2}$ inches, which implies a height of 2337 $\frac{1}{2}$ fathoms.

'In the town of Quanca-Velica, the mercury stands at 18 inches $1\frac{1}{2}$ line, which gives a height of 1949 fathoms.

'Don Antonio Ulloa informed me, that he detached these shells from a very thick bank, the extent of which he did not know: The shells are of the large pilgrim or scallop kind.'

vel of the sea, the surface of the globe has been covered with the waters, and that they remained long enough for the production and multiplication of shell-animals; for the quantity of them is so great, that their spoils often form large banks, which extend many miles in length. They compose a considerable part of the exterior strata of the earth; for calcarious substances, or the spoils of shells, are very common in most countries. But, at high points of elevation, *i. e.* above 1500 or 2000 fathoms, the summits of the mountains generally consist of pure rock, granite, and other vitrifiable bodies produced by the primitive fire, which contain no shells, madrepores, or any thing that has a relation to calcarious substances. We may, therefore, conclude, that the sea has never reached, or at least for a short time only, those most elevated parts of the earth.

To support the testimony of Don Ulloa, concerning the shells found in the Cordelieres, we shall add that of Alphonso Barba. He tells us, that, in the most mountainous part of Peru, there are shells of all sizes, some of them concave, others convex, and the whole finely impressed *. Hence America, as well as the other quarters of the globe, has been covered with the waters of the sea. The first observers were probably induced to think that no shells were to be found

* Metallurgie d'Alphonso Barba, tom. 1. p. 64.

in the Cordelieres, because most of these mountains, which are the highest on this globe, are either active or extinguished volcano's, the eruptions of which have covered all the adjacent countries with burned substances : Of course, all the shells which might have been found there, are not only buried, but completely destroyed. It is not, therefore, surprising that no marine productions have been discovered around these mountains, which either are at present, or have formerly been volcano's ; for the territories which surround these mountains must be composed entirely of ashes, scoriae, glass, lava, and other burned or vitrified bodies. Thus the notion that the sea never covered the mountains, has no other foundation than this circumstance, that, on the tops of several of them, no shells or other productions of the sea are now to be seen. But, as we find, in an infinite number of places, and even as high as 1500 or 2000 fathoms, shells and other sea-bodies, it is evident, that there are few ridges of mountains which have not been covered with the ocean ; and that the spots where no shells appear only show that the animals which produce them have never dwelt there, or that the motion of the waters has not transported thither marine productions, as it has done in every other part of the globe.

We are next informed, that some fishes and plants can live and vegetate in waters so hot as

from 50 to 60 degrees of the thermometer. There are many examples of plants growing in the hottest bath-waters; and M. Sonnerat found fishes in water the heat of which was so great that he durst not plunge his hand into it. 'Two leagues from Calamba,' says he, 'I found in the isle of Luçon, near the village of Bally, a brook, the water of which was so hot that Reaumur's thermometer, when plunged into it, about a league from its source, stood at the 69th degree. Upon perceiving such a degree of heat, I imagined, that all the productions of nature must have been extinguished upon the margin of this brook. But I was much surpris'd when I saw three vigorous shrubs, the roots of which were immersed in this boiling water, and their branches surrounded with its vapour. The heat was so great, that, when the swallows attempted to cross the water at seven or eight feet high, they uniformly fell down dead. One of these shrubs was an *agnus castus*, the other two were a species of broom called *aspalathus*. During my abode in this village, I constantly drank this water after it was cooled. Its taste seemed to be earthy and ferruginous. Several baths are constructed along this brook, and their degrees of heat are proportioned to their distance from its source. When I visited the first bath, my surprise was increased: In this water, which

' was

' was so hot that I durst not plunge my hand
 ' into it, I saw fishes swimming. I used every
 ' effort to procure some of them ; but their agi-
 ' lity, and the want of address in the people,
 ' prevented me from succeeding. I examined
 ' them in the water ; but I could not distinguish
 ' their genus, on account of the vapour rising
 ' from the water. They had brown scales,
 ' and the largest of them were about four inch-
 ' es long. I could not learn how these fishes
 ' had got into the baths.' The testimony of
 M. Sonnerat is strengthened by that of M. Pre-
 vost, who travelled with him into the interior
 parts of the isle of Luçon. ' You was right,' M.
 Prevost remarks, ' to communicate to M. de
 ' Buffon the observations you collected when
 ' we travelled together. You desire me to con-
 ' firm in writing what surprised us so much in
 ' the village of Bally, situated on the margin of
 ' the Laguna of Manilla, at *Los-bagnos*. I am
 ' sorry I have not a copy of our observations
 ' made with Reaumur's thermometer. But I
 ' clearly recollect, that the water of the small
 ' brook which passed through this village to fall
 ' into the lake, made the mercury rise to 66
 ' or 67 degrees, though it was plunged into the
 ' water at a league's distance from the source of
 ' the brook. The margins of this brook were
 ' covered with a very fine green carpet. You
 ' cannot have forgot the *agnus castus* we saw

‘ in flower, the roots of which were moistened
 ‘ with the water of the brook, and its stem and
 ‘ branches perpetually surrounded with its
 ‘ steams. . The curate of the village likewise
 ‘ assured, me that he had seen fishes in this same
 ‘ brook. This fact I cannot certify. But I
 ‘ saw fishes in one of the baths, the heat of
 ‘ which raised the mercury to 48 and 50 de-
 ‘ grees *.’

I know not whether fishes have ever been found in our hot waters ; but it is certain that the bottom of the hottest of them is covered with plants. M. l’Abbé Mazéas informs us, that, in the almost boiling water in the Solfatara of Viterbe, the bottom of the basin is covered with the same plants which grow at the bottoms of lakes and ditches †.

Of Giants.

From monuments which still remain, it appears, that gigantic animals of different kinds have formerly existed.

The large teeth with blunt knobs which I formerly described, indicate the existence of an animal, whose magnitude greatly surpassed that of the elephant. But this gigantic species is now entirely annihilated. Other large teeth, the grinding face of which resembles spades on cards,

* Voyage à la Nouvelle Guinée, par M. Sonnerat, Correspondant de l’Académie Royale des sciences, et du Cabinet du Roi, p. 38. &c.

† Mem. des Savans étrangers, tom. 5. p. 325.

cards, like those of the hippopotamus, and which are four times larger than the teeth of the present hippopotamus, show that there has been a very gigantic species of this animal. The enormous thigh-bones, which far exceed the dimensions of those of our elephants, demonstrate the same thing with regard to the elephant species.

In the year 1772, there was found, near Rome, a petrified head of an ox, which P. Jacquier describes in the following manner. 'The length of the front between the two horns, is 2 feet 3 inches; the distance between the orbits of the eyes, 14 inches, and that from the superior part of the front to the orbit of the eye one foot six inches; the circumference of the horn at the base, is one foot six inches; the length of the horn four feet; and the distance between the ends of the horns three feet. The internal part of this petrefaction is extremely hard. This head was found at Puzzolani more than 20 feet below the surface of the ground *.'

'In the year 1768, I saw, in the cathedral of Strasburg, a large horn of an ox suspended by a chain to a pillar near the choir. It appeared to be three times bigger than those of our largest oxen. As it was hung very high, I could not take the exact dimensions, but I

X 3

'judged

* Gazette de France du 25. Septembre 1772, *Article de Rome.*

'judged it to be about $4\frac{1}{2}$ feet long, and from 7 to 8 inches in diameter at the base *.'

Lionel Waffer relates, that he saw, in Mexico, bones and teeth of a prodigious size: Among others, he saw a tooth 3 inches broad and 4 in length. Having consulted the most intelligent people of the country, they concluded that the head could not be less than a yard broad †.

It is, perhaps, the same head which Acofta mentions: 'I saw,' says he, 'a grinder which astonished me by its enormous size; for it was as large as a man's fist.' P. Torquemado, a Franciscan, relates, that he had in his possession a grinder, twice as large as a man's fist, and which weighed two pounds. He adds, that, in the city of Mexico, and in the Convent of St Augustine, he saw a thigh bone so large, that the individual to which it belonged must have been from 11 to 12 cubits high, *i. e.* 17 or 18 feet; and that the head must have been as big as one of the large pitchers used in Castille for holding wine.

Phillippe Hernández informs us, that there were found, at Tezcaco and Tofuca, several bones of an extraordinary magnitude; and that among these there are grinding teeth five inches broad and ten high; from which he concludes, that

* Note communicated to M. de Buffon by M. Grignon, Sept. 24. 1777.

† Waffer's travels in America, p. 367.

that the size of the head must have been so enormous that two men could not have embraced it with their arms. Don Lorenzo Boturini Benaduci likewise tells us, that, in New Spain, and particularly in the heights of Santa fé, and in the territories of Puebla and Tlascala, they find enormous bones, and grinders, one of which, preserved in the Royal Cabinet, is a hundred times larger than the largest human teeth *.

The author of this *Gigantologie Espagnole* attributes these enormous teeth and bones to giants of the human species. But, is it credible that men ever existed whose heads were eight or ten feet in circumference? Is it not equally astonishing that, in the species of the hippopotamus or elephant, there have been individuals of this magnitude? We are, therefore, led to think, that these enormous teeth are of the same kind with those lately found in Canada near the river Ohio, which we ascribed to an unknown animal, whose species formerly existed in Tartary, in Siberia, and in Canada, and which extended from the Illionois as far as Mexico. As the Spanish authors mention not that elephants tusks were found in New Spain along with these large grinders, it is probable that a species different from that of the elephant formerly existed

* *Gigantologie Espagnole*, par le P. Torrubia, *Journal étranger*, Nov. 1760.

isted there, to which these large grinders belonged, and that this species was diffused as far as Mexico. Besides, the large teeth of the hippopotamus seem to have been anciently known; for St Augustine tells us, that he saw a grinder so large, that, if divided, it would have made a hundred teeth of an ordinary man *. Fulgosa likewise remarks, that teeth were found in Sicily, each of which weighed three pounds †.

John Sommer relates, that he found, near Chatham in Canterbury, at the depth of seventeen feet below the surface of the earth, monstrous bones, some of them entire, and others broken. He likewise found four entire teeth, each of them weighing more than half a pound, and nearly as large as a man's fist. The whole four were grinders, and, except in magnitude, they pretty much resembled human teeth. He farther remarks, that Louis Vives mentions a grinder still larger, which was shewn him for a tooth of St Christopher. He adds, that Acoſta ſaw in India a ſimilar tooth dug out of the earth, along with ſeveral other bones, which, when arranged in proper order, represented a man of a monstrous ſtature. We might have formed the ſame idea, ſays Mr Sommer, concerning the teeth dug out of the earth near Canterbury, if
bones

* De Civitate Dei, lib. 15. cap. 9.

† Lib. 1. cap. 6.

bones had not been found in the same place, which could not belong to the human species. Several persons who examined these bones, judged them to be the bones and teeth of the hippopotamus. Two of these teeth are engraved in the philosophical transactions, No. 272. fig. 9.

From these facts we may conclude, that most of those large bones found under the surface of the earth belong to the elephant and hippopotamus : But it seems to be certain, that, by comparing the enormous teeth with blunt knobs, with those of the elephant and hippopotamus, they have belonged to an animal much larger than either, and that the species of this prodigious animal no longer exists.

Among the present elephants it is extremely rare to find a tusk of six feet in length. The longest are generally from five to six and a half feet ; and, of course, the ancient elephant, which produced a tusk of ten feet long, whose fragments are in our possession, was a gigantic species. The immense thigh-bone in the Royal Cabinet confirms the same conclusion.

The same remark is applicable to the species of the hippopotamus. I caused two of the largest grinders to be extracted from the largest head of the hippopotamus in the 'Royal Cabinet : One of them weighed ten, and the other nine and a half ounces. I then weighed two teeth, the one found in Siberia, and the other in
Canada.

Canada. The first weighed two pounds twelve ounces, and the second two pounds two ounces. Hence these ancient hippopotamis were gigantic when compared with those now existing.

The example already given of the enormous petrified head of an ox, found in the environs of Rome, proves, that there have likewise been prodigious giants in this species of quadruped, which we are also enabled to shew, by several other monuments of antiquity. In the Royal Cabinet, we have, 1. A fine greenish horn, which is very smooth and well turned, and evidently belongs to the ox. The circumference at the base is 25, and its length 42 inches. Its cavity contains $11\frac{1}{4}$ Paris pints of liquor; 2. The core, or internal bone of an ox's horn, which weighs seven pounds; whilst the largest core of the horns of our oxen exceeds not the weight of one pound: This internal bone was presented to the Royal Cabinet by M. le Comte de Tressan, a man of taste, and a good Natural historian; 3. Two internal bones of an ox's horn attached to a portion of the cranium, were found in beds of turf, at the depth of 25 feet, between Amiens and Abbeville, and transmitted to me for the Royal Cabinet. The whole weighed 17 pounds; and each horn-bone, when separated from the cranium, weighed at least $7\frac{1}{2}$ pounds. I compared the dimensions, as well as the weight of these different bones; that

that of the largest ox to be found in Paris was only 13 inches long, and 7 in circumference at the base. But, of the two dug out of the earth, the one was 24 inches long, and 12 in circumference at the base, and the other 27 inches in length, and 13 in circumference. These facts are more than sufficient to shew, that, in the species of the ox, as well as in those of the hippopotamus and elephant, prodigious giants have formerly existed.

With regard to the human species, individual giants have been produced not only in Asia, but in every climate; for, even in our own days, we see gigantic men in every country. We lately saw a giant who was born in Finland, on the very confines of Lapland. But we are not equally certain, that permanent races, and far less entire nations of giants, ever existed. However, the testimony of ancient authors, and especially those of Holy Writ, seem clearly to indicate, that races of giants formerly existed in Asia. In the book of Numbers, chap. 13. verse 33. it is said, *And there we saw giants, the sons of Anak, which came of the giants: and we were in our own sight as grasshoppers, and so we were in their sight.* Though this description may have the appearance of 'exaggeration, which is common in the oriental style, it is plain that these giants were very large.

In 2 Samuel, chap. 21. verse 20. a giant is mentioned

mentioned of the race and family of Goliath, who had six fingers and toes on his hands and feet : In the same book, there are several other passages which prove the existence and destruction of giants.

In Joshua, chap. 2. verse 22. it is said, that *there was none of the giants of the race of the Anakims left in the land of the children of Israel ; only in Gaza, in Gath, and in Ashdod, there remained.*

Philo, St Cyrillus, and several other authors, seem to think, that the word *giants* means only proud and impious men, and not men of an extraordinary stature. But there is no foundation for this opinion ; since the amazing height and strength of these men are often described.

The prophet Amos informs us, that the Lord *destroyed the Amorite, whose height was like the height of cedars, and he was strong as the oaks.*

Ogg, king of Bashan, was nine cubits high, and Goliath ten cubits and one palm. Ogg's bed was nine cubits, or thirteen and a half feet long, and four cubits, or six feet, broad. The breast-plate of Goliath weighed 208 pounds 4 ounces, and the blade of his lance 25 pounds.

These evidences are sufficient to prove, that there formerly existed in the continent of Asia, not only individuals, but races of giants, who have been destroyed, and the last of whom appeared in the days of King David. Nature, who
never

never loses any of her rights, sometimes resumes her former powers of production ; for, in almost every climate, men of an extraordinary stature, *i. e.* of seven and a half, eight, and even nine feet high, occasionally appear. Beside the examples already given, many others are to be found, both in ancient and modern authors, of giants of ten, twelve, fifteen, and eighteen feet high. But these last dimensions, I am persuaded, ought to be greatly reduced. The bones of elephants have often been mistaken for human bones. Besides, Nature, in her present appearance, presents no species with such great disproportions, except, perhaps, that of the hippopotamus ; for the teeth of those found in the bowels of the earth are at least four times larger than the teeth of the hippopotamus which now exists.

The bones of the supposed king Teutobochus, found in Dauphiny, gave rise to a dispute between Habicot, a surgeon in Paris, and Riolan, the famous anatomist. Habicot, in his *Gigantologie*, tells us, that these bones were taken out of a brick sepulchre, 18 feet below ground, and surrounded with sand. He neither gives an exact description, nor the number of these bones. He asserts that they are human, because they belonged to no other animal. He adds, that some masons, when working to Seignio Langon, a gentleman of Dauphiny, on the 11th day

day of January 1613, discovered this tomb near the ruins of the castle of Chaumont ; that the tomb was built with brick ; that it was 30 feet long, 12 broad, and 8 high ; that it was covered with a gray stone, on the middle of which was engraved, *Theutobochus rex* ; that, when the tomb was opened, a human skeleton appeared, which was $25\frac{1}{2}$ feet long, 10 broad at the shoulders, and 5 thick ; that, before touching these bones, the head was measured, and it was 5 feet in length, and 10 in circumference. Here it is worthy of remark, that the proportion between the length of a human head and that of the body, is not a fifth, but a seventh and one half ; so that this head of 5 feet supposes the body to have been $37\frac{1}{2}$ feet in length. Lastly, Habicot tells us, that the under jaw was 6 feet round, and the orbits of the eyes 7 inches ; that each clavicle was 7 feet long ; and that most of these bones, after being exposed to the air, crumbled into dust.

In the same year 1613, Dr Riolan published a tract under the title of *Gigantomachie*, in which he maintains, that Habicot, in his *Gigantosteologie*, had given false measures of the body and bones of the pretended giant Teutobochus ; that Riolan measured the thigh-bone and the bone of the leg together with the astragalus joined to the calcaneum ; that they exceeded not $6\frac{1}{2}$ feet, even including the os pubis ; and, of course, that
the

the length of the giant could be only 13 feet, instead of 25. He then gives his reasons for denying these bones to be human; and concludes, that the bones exhibited by Habicot belong not to man, but to the elephant.

A year after the publication of Habicot's *Gigantosteologie* and Riolan's *Gigantomachie*, a pamphlet appeared under the title of *the Imposture, concerning supposed human bones falsely attributed to King Teutobochus, discovered*. In this pamphlet, the bones are denied to be human, and supposed to have been engendered by some virtue in the earth. Another pamphlet was published without a name, in which it is said, that, among these bones, some were human and others not.

In 1618, Riolan published his *Gigantologie*, in which he maintains, that the bones in question were not only not human, but that men, in general, were never larger than they are at present.

In the same year, Habicot replied to Riolan: He says, that he presented his *Gigantosteologie* to Louis XIII.; that, about the end of July in the year 1613, the bones mentioned in this work were exposed to the eye of the public; and that they are real human bones. He quotes a number of examples from ancient and modern authors, to prove that men of immense stature have existed. He persists in maintaining, that the calcaneum, tibia, and femur of the giant Teutobochus, when
joined

joined to each other, were more than 11 feet in length.

He next gives letters written to him at the time these bones were discovered, and which seem to confirm the reality both of the tomb and of the bones of the giant Teutobochus. From a letter written by Seignior de Langon, dated St Marcellin, in Dauphiny, and another by the Sieur Masurier, a surgeon at Beaurepaire, it appears, that silver coins were found along with the bones. The first letter contains the following passage: 'As his Majesty,' says Seignior de Langon, 'is desirous of having the remaining bones of King Teutobochus, and the silver coins found in the tomb, I declare, that your adversaries are ill informed, and that, if they knew the matter more perfectly, they would not entertain any doubts that these bones really belong to the human species. The physicians of Montpellier came here, and would have given any money to purchase the bones. M. le Maréchal de Lefdiguières made them be carried to Grenoble; and the physicians and surgeons of that place recognised them to be human bones. This fact, of course, can only be denied by persons who are ignorant of the real circumstances.'

In this dispute, neither Riolan nor Habicot, the one a physician and the other a surgeon, have had sense enough to give an exact description

tion of the bones in question. Both of them, actuated by passion and a party-spirit, have written in a style which destroys all confidence in their assertions. Hence it is extremely difficult to ascertain the species to which these bones really belonged. But, if they were found in a brick tomb, with a stone cover, upon which the words *Teutobochus Rex* were inscribed; if coins were found in this tomb; if it contained but a single skeleton of 24 or 25 feet in length; and, if Seignior Langon's letter relates nothing but truth, the general fact, *i. e.* the existence of a giant of 24 feet high, unless we should suppose a very extraordinary concurrence of falsehoods, could not admit of a doubt. But the fact is by no means proved, in a manner so explicit as not to leave room for much hesitation. It is true, that several authors, otherwise worthy of credit, have mentioned giants as large, and even larger. Pliny relates *, that, by an earthquake in Crete, a mountain was split, and discovered a human body of 16 cubits long, which some ascribed to that of Otus, and others to that of Orion. 16 cubits are equal to 24 feet, which is the same length with the skeleton of King Teutobochus.

In a Memoir of M. le Cat, an Academician of Rouen, we have an enumeration of several

VOL. IX. Y giants

* Lib. 7. cap. 16.

giants of enormous magnitude, namely, two, whose skeletons were found near Athens, of which one was 36 and the other 34 feet high; another of 30 feet was found in Sicily near Palermo, in the year 1548; another of 33 feet was likewise found in Sicily in the year 1550; and another was also found in Sicily, near Mazarino, which was thirty feet long.

These testimonies notwithstanding, it is difficult to believe that men of 30 or 36 feet high ever existed: It is perhaps too much to believe in the existence of giants of 24 feet high. However, evidences multiply, become more positive, and gradually increase, in proportion as the dimensions decrease. M. le Cat relates, that, in the year 1705, there was found, near the banks of the river Morderi, at the foot of Mount Crussol, the skeleton of a giant which measured $22\frac{1}{2}$ feet; and that the Dominicans of Valencia have part of the tibia with the joint of the knee.

Platerus, a celebrated physician, asserts, that he saw at Lucerne the skeleton of a man, which was 19 feet in length.

The giant Ferragus, slain by Rolland, nephew to Charlemagne, was 18 feet high.

In the sepulchral caverns of the island of Teneriff, a skeleton was found, which measured 15 feet, and in whose jaws were 80 teeth. These three facts, as well as the preceding, are related

ted in M. le Cat's essay concerning giants. He mentions another skeleton found in a ditch near the convent of the Dominicans at Rouen, the skull of which held a bushel of corn, and the bone of the leg was 4 feet long: The whole body, of course, must have been from 17 to 18 feet in length. Upon the tomb of this giant, the following inscription was engraved: *Here lies the noble and puissant Seignior le Chevalier Ricon de Valmont, together with his bones.*

In the Journal Littéraire of Abbé Nazari, we are told, that, in High Calabria, in the month of July 1665, there was dug out of the gardens of Signior de Tivolo, a skeleton of 18 Roman feet long; that the head was $2\frac{1}{2}$ feet; that each grinder weighed about an ounce and a third, and the other teeth three quarters of an ounce; and that this skeleton was bedded in a mass of bitumen.

Hector Boethius, in his history of Scotland, relates, that the bones of a man, ironically called *Little John*, are still preserved, who was supposed to have been 14 feet high.

In the Journal des Savans, anno 1692, there is a letter from P. Gentil, professor of philosophy at Angers, in which he says, that, having been informed of a gigantic body discovered nine leagues from the town of Lassé, he went to the spot to satisfy himself concerning the truth of the fact. He learned from the curate of the

place, that, in digging his garden, a sepulchre was discovered which contained a body of 17 feet 2 inches long. There was no skin on the body. This body had others between its arms and legs, which might have been the person's children. In the same place, there were discovered fourteen or fifteen other sepulchres, some of them 10 feet, others 12, and others 14 feet long, which contained bodies of the same dimensions. The sepulchre of this giant continued exposed to the air more than a year; but, as it attracted too many visitors to the Curate, he again covered it with earth, and planted three trees in the place. These sepulchres were constructed with a stone which resembled chalk.

Thomas Molineux saw, in a cabinet at Leyden, a prodigious human frontal bone. From its junction with the nose to the sagittal suture, it was $9\frac{1}{11}$ inches; its length was $12\frac{2}{5}$ inches, and its thickness half an inch, *i. e.* in every dimension it was double that of an ordinary frontal bone. Hence the person to whom this gigantic bone belonged must have been twice the common size of a man, or at least 11 feet high. This bone was unquestionably human; and it seemed not to have acquired this uncommon magnitude by the effects of any disease; for its thickness was exactly proportioned to its other dimensions, which never happens in diseased bones*.

M.

* Phil. Transf. No 168. art. 2.

M. Klein tells us, that he saw, in the cabinet of M. Witreu at Amsterdam, a frontal bone, from the dimensions of which it appeared, that the person to whom it appertained must have been 13 feet 4 inches high, i. e. about $12\frac{1}{2}$ French feet*.

After all these facts, I shall leave my readers in the same embarrassment as myself, with regard to the real existence of giants of 24 feet in length. I cannot persuade myself, that at any time, or by any circumstances whatever, the human body could be elevated to such immoderate dimensions. But, at the same time, it is unquestionable, that giants of 10, 12, and perhaps even of 15 feet high, have existed; and it is almost certain, that, in the primaeval ages of Nature, not only gigantic individuals, but even permanent and successive races of giants, were produced, of which that of the Patagonians is the only remaining example.

TO prove that some of the fishes and plants found in coal and slate belong to species which no longer exist, the Count de Buffon produces the following facts and observations.

With regard to this subject, we shall remark, with M. Lehmann†, that there are no impres-

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sions

* Phil. Trans. No 456. art. 3.

† Tom. 3. p. 407.

sions of plants in slate, except when it accompanies pit-coal ; and that, on the contrary, impressions of fishes are seldom found but in coppery slates.

It has likewise been remarked, that, in the district of Mansfield, the beds of slate which contain petrified fishes, are covered with a stratum of stones called *stinking stones*. This stratum is a species of gray slate, which has derived its origin from stagnant water, where the fishes had corrupted before they were petrified*.

M. Hoffman, when treating of slates, says, that the petrified fishes found in these stones have not only been living creatures, but that the strata of slate have originated from muddy water, which, after fermenting and petrifying, subsided in thin laminae or beds.

‘ In the slate of Angers,’ says M. Guettard,
 ‘ there are sometimes impressions of plants and
 ‘ fishes, which merit the greater attention, because the impressions of the plants represent
 ‘ marine *fuci*, or sea-wreck, and those of the
 ‘ fishes represent different species of the crustaceous tribes, the impressions of which are
 ‘ more rare than those of scaly fishes, or shells.
 ‘ He adds, that, after consulting several authors
 ‘ who treat of fishes and crustaceous animals,
 ‘ he could not discover any of them that resembled

* Lecheroth, Journal Oeconomique, Juillet 1752.

'sembled the impressions in question, except
 'the sea-louse, which has some resemblance to
 'them; but it has thirteen rings, and the im-
 'pressions on the slates have only seven or eight:
 'The impressions of these fishes are generally
 'interspersed with a whitish pyritous substance.
 'It is remarkable, that, in the slates of Angers,
 'as well as in those of other countries, the im-
 'pressions of fishes are frequent, and those of
 'shells are exceedingly rare, whilst the latter are
 'very common in lime-stone *.'

Many proofs might be given that all pit-coal
 is composed of the spoils of vegetables, mixed
 with bitumen and sulphur, or rather with the
 vitriolic acid, which is perceived when the coal
 is burning. We often find a great quantity of
 vegetables in the upper strata of coal; and, in
 proportion as we descend, we see traces of the
 decomposition of the same vegetables. There
 are species of coal which are not fossil wood:
 That found at Sainte-Agnés, near Lons-le-Sau-
 nier, has a perfect resemblance to logs or trunks
 of fir, in which we distinctly perceive the marks
 of each year's growth, as well as the pith.
 These trunks differ only from common fir by
 being somewhat oval, and by their rings being
 concentric ellipses. They exceed not a foot in
 circumference, and their bark is very thick and
 full of furrows, like that of old firs. But the
 bark

* Mem. de l'Acad. des Sciences, année 1757, p. 52.

bark of common firs, of the same size, is always smooth.

'I found,' M. de Genfanne remarks, 'several veins of this kind of coal in the diocese of Montpellier: Here the trunks are very large; their texture resembles that of chestnut-trees from three to four feet in circumference. These fossils, when burning, have only a slight odour of asphaltis. Their flame and embers resemble those of wood. They are found near the surface of the earth, and commonly indicate the existence of real pit-coal at greater depths *.'

These ligneous coals ought to be regarded as wood deposited in a bituminous earth, from which they derive their fossil quality. They are found only in earths of this kind, and always near the surface. They sometimes form the stratum immediately above the seams of real coal. Some of them, which have been impregnated with a small quantity only of bitumen, preserve the shades and colour of wood. 'I found this species,' says M. de Genfanne, 'at Cazarets, near Saint-Jean-de-Culeul, four leagues from Montpellier. But, when broken, this fossil commonly presents a smooth surface, perfectly similar to that of jet. In the same canton, near Aseras, there is fossil wood changed into

* Hist. Nat. du Languedoc, par M. de Genfanne, tom. I. p. 20.

‘ a white ferruginous pyrites. The mineral
 ‘ matter occupies the heart of the wood ; and
 ‘ we distinctly perceive the woody substance
 ‘ furrowed and partly dissolved by the mineral
 ‘ acid *.’

After such proofs, related by M. de Genfanne himself, who is otherwise a good mineralogist, I acknowledge, that I was surprised to see him ascribe the origin of coal to clay more or less impregnated with bitumen. This notion is not only refuted by his own facts, but we shall be convinced by those I am about to relate, that we ought to attribute the origin of every species of coal to the spoils of vegetables mixed with bitumen.

I agree with M. de Genfanne, that neither this fossil wood, nor turf, can be considered as coal completely formed. That found near Lons-le-Saunier has been recently examined by the President de Ruffey, a learned Academician of Dijon : He remarks, that this fossil wood makes a near approach to the nature of pit-coal ; and that it is found within two or three feet of the surface through an extent of two leagues ; that it is from three to four feet thick ; that we easily distinguish the species of wood to be oaks, horn-beams, and trembling poplars ; that this wood is sometimes in the form of bundles or faggots ; that the bark of the logs is well preserved ;

* Hist. Nat. du Languedoc, tom. 1. p. 54.

preserved; that the annual circles, the cuts made by the axes, and, at different distances, collections of chips, are plainly distinguishable; that this wood converted into coal is excellent for soldering iron; that, when burning, it diffuses a fetid odour; and that allum has been extracted from it*.

* Near the village called *Beichlitz*, about a league from the town of Halle, two strata, composed of a bituminous earth and fossil wood, (of which there are several mines in the country of Hesse,) were discovered. It is similar to that found in the village of Sainte-Agnès in Franche-comté, two leagues from Lons-le-Saunier. This mine is in the territory of Saxe. The first stratum lies at the depth of three fathoms and a half, and is from eight to nine feet thick. To arrive at it, we cut through a white sand, then a whitish gray clay, which is three feet thick: Still deeper, we meet with a considerable thickness both of sand and clay, which cover the second stratum. This stratum is only from three and a half to four feet thick. We sounded deeper, but found no other strata of that kind.

These strata are horizontal; but they sink or rise nearly in the same manner as common strata. They consist of a brown bituminous earth, which is friable when dry, and resembles

* Mem. de l'Acad. de Dijon, tom. i. p. 47.

'bles corrupted wood. Pieces of wood of all
'sizes are found, which, when taken from the
'mine, where they are soft, must be cut with an
'ax. This wood, when dry, breaks easily.
'When broke, it shines like bitumen; but
'we distinctly perceive in it the whole organi-
'zation of wood. It is less abundant than the
'bituminous earth, and the workmen lay it
'aside for their own use.

'A bushel or two quintals of bituminous
'earth sells for eighteen or twenty French
'fous. In these strata there are pyrites; they
'are of a vitriolic nature; when exposed to the
'air they effloresce and turn white: But the bi-
'tuminous matter is of little value, as it gives
'but a feeble heat *.

Hence this species of fossil wood, found so
near the surface of the earth, must be a much
more recent production than common pit-coal,
which is almost constantly sunk very deep. But
this idea does not preclude the ancient coal from
being formed of the spoils of vegetables; since,
in the deepest coal-mines, we recognise woody
substances, and several characters which belong
to vegetables only. Besides, there are some ex-
amples of fossil wood found in large masses, and
in extensive beds, under strata of free-stone and
calcareous rocks. Hence there is no other dif-
ference

* Voyages Metallurgiques de M. Jars, p. 320.

ference between real pit-coal and these charred woods, but what arises from the degree of decomposition, and from a greater or smaller impregnation with bitumen. The basis of their substance is the same, and both derive their origin from the spoils of vegetables.

M. le Monnier, one of the King's physicians, and a learned botanist, found, in the schist, or false slate, which traverses a large field of pit-coal in Auvergne, the impressions of several ferns, almost the whole of which were unknown to him: He only thought, that he could distinguish the impression of the leaves of the osmund-royal, of which he saw but one example in all Auvergne*.

It were to be wished that botanists would examine more accurately the impressions of plants found in pit-coal and in slate. The impressions of plants, as well as those of crustaceous animals, shells, and fishes, found in these minerals, should be drawn and engraved; for all this labour is necessary to enable us to determine the actual or the past existence of these species, or even their relative antiquity. At present, we are satisfied, that most of them are unknown, and that, in those which have been referred to known species, the differences are always so great as to create hesitation.

The

* Observations de Hist. Nat. par M. le Monnier, p. 193.

The Count de Buffon remarks, That the motion of the waters from east to west has diminished the surface of the earth on the west side; and that, in every continent of the globe, the declivity is more rapid on the west than on the east coasts. This is evident in the continent of America, the declivities of which are extremely rapid and abrupt toward the western seas; but, towards the eastern coasts, the lands stretch by a gentle declivity, and generally terminate in large plains. In Europe, the line that forms the summit of Great Britain, which runs from north to south, is much nearer the western than the eastern ocean: For the same reason, the seas to the west of Britain and Ireland are much deeper than the sea which separates Britain and Holland. The ridge of Norway is much nearer the ocean than the Baltic sea. The mountains which form the general summit of Europe are much higher toward the west than the east; and, if we take a part of this summit, from Switzerland to Siberia, it is much nearer the Baltic and White Seas, than the Black Sea and the Caspian. The Alps and Apennines are nearer the Mediterranean than the Adriatic sea. The chain of mountains which runs from Tirol to Dalmatia, and as far as the Morea, in a manner skirts the Adriatic sea; but the opposite coasts are much lower. In Asia, if we follow the chain which extends from the Dardanelles to the

the strait of Babelmandel, we shall find that the summits of Mount Taurus, of Libanus, and of all Arabia, skirt the Mediterranean and the Red Seas ; and that, to the east, there are vast territories where the long coursed rivers run, and at last empty themselves in the Persian Gulf. The summit of the famous mountains of Gata approaches nearer to the western than the eastern seas. The ridge which extends from the west frontiers of China to the point of Malacca, is nearer the west than the east sea. In Africa, the chain of Mount Atlas sends rivers to the sea of the Canaries, whose courses are much shorter than those which run into the interior parts of the Continent, and, after traversing vast tracts of country, lose themselves in lakes or great marshes. The high mountains to the west of Cape Verd, and through all Guiney, after turning round Congo, join the mountains of the Moon, and stretch as far as the Cape of Good Hope, occupy pretty uniformly the middle of Africa : We will perceive, however, on examining the sea to the east and west, that the sea on the east is not deep, and is interspersed with a great number of islands ; whilst, to the west, it is deeper, and has but few islands ; so that the deepest places of the western sea are much nearer this chain of mountains than the deepest places of the eastern or Indian seas.

Hence

Hence we see that, in general, all the points of partition in the great continents are always nearer the west than the east seas; that the plains of these continents are always lengthened toward the east, and shortened toward the west; that the seas on the west coasts are deeper, and have fewer islands than those on the east; and that, in all these seas, the west coasts of the islands are always higher, and the seas which wash them deeper, than those on the east.

We are next told, that there are animals, and even men, so brutish, that they rather languish in the ungrateful soil where they were brought forth, than take the trouble of removing to a more comfortable situation. Of this, says the Count de Buffon, I can give a striking example: The Maillés, a small savage nation in Guiana, near the mouth of the river Ouassa, have no other habitation than trees, upon which they dwell during the whole year, because their country is always more or less covered with water. They never descend from these trees, except when they go in canoes in quest of subsistence. This is a singular example of a stupid attachment to a native country; for these savages, in order to procure habitations on land, have only to remove a few leagues from those drowned savannahs which gave them birth, and which they obstinately refuse to abandon. This
fact

fact is mentioned by some voyagers *, and has been confirmed to me, by several witnesses, who have lately seen this small nation, which consists of three or four hundred savages. They keep themselves above the water by means of the trees. There they remain the whole year. During the eight or nine rainy months, their country is a large sheet of water; and, during the four summer months, their soil consists of a dirty mud, upon which a crust of five or six inches thick is formed. This crust is rather composed of herbage than of earth, under which is a considerable depth of stagnant and stinking water.

The Caspian Sea, the Count de Buffon remarks, was formerly much larger than it is at present.—‘In traversing,’ says M. Pallas, ‘the immense deserts which lie between the Wolga, the Jaïk, the Caspian Sea, and the Don, I observed, that these *steppes* or sandy deserts, are every way surrounded with an elevated border, which embraces a great part of the beds of the Jaïk, Wolga, and Don; and that these deep rivers, before they penetrated this inclosing belt, were full of islands and shoals, till they began

* The Maillés, one of the savage nations of Guiana, dwell along the coast. Their country is often covered with water. They, therefore, build their cabbins upon trees, to the feet of which they fasten their canoes, in which they sail in quest of subsistence; *Voyage de Desmarchais, tom. 4. p. 352.*

' began to fall into the deserts where the great
 ' river Kuman loses itself in the sands. From
 ' these observations I conclude, that *the Caspian*
 ' *Sea has formerly covered all these deserts*; that
 ' it anciently had no other margins than those
 ' elevated belts which every where surround the
 ' deserts; and that it has communicated, by
 ' means of the Don, with the Black Sea, even
 ' supposing this sea, as well as that of Azoff, had
 ' never made a part of it *.

M. Pallas is unquestionably one of our most
 learned naturalists; and it is with the greatest
 pleasure that I see him here entirely of my opi-
 nion with regard to the ancient extent of the
 Caspian, and the probability that it formerly
 communicated with the Black Sea.

There have been greater and more frequent
 revolutions in the Indian ocean than in any o-
 ther part of the globe. But, says the Count de
 Buffon, tradition has only handed down to us
 the submerſion of Taprobana.——The most an-
 cient tradition we have of the sinking of coun-
 tries in the south is that of the loss of Taprobana,
 of which the Maldivas and Laquedivas are sup-
 posed to have been formerly a part. These
 islands, as well as the rocks and banks which
 prevail from Madagascar to the point of India,

VOL. IX.

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* Journal Historique et politique, mois de Novembre 1773,
 Art. Petersbourg.

seem to indicate the summits of countries that united Africa to Asia ; for almost all of these islands have, on the north side, lands and banks which stretch very far under the waters.

It likewise appears, that the islands of Madagascar and Ceylon were formerly united to the adjacent continents. Most of these separations and revolutions in the southern seas have been produced by the sinking of caverns, by earthquakes, and by explosions of subterraneous fires. But lands have also been carried off by the flow and gradual movement of the waters from east to west. The places where these effects are most apparent are the regions of Japan, of China, and of all the eastern parts of Asia. The seas situated to the west of China and Japan seem to be accidental productions, and perhaps more recent than our Mediterranean.

The islands of Sunda, the Moluccas, and the Philippines, present nothing but countries which have been overturned ; and they are still full of volcano's. There are many volcano's in the Japanese islands ; and Japan is reputed to be more subject to earthquakes than any other part of the globe : It also gives rise to a number of hot fountains. The greater part of the islands in the Indian ocean present only peaks or summits of detached mountains, which continually vomit fire. The isles of France and Bourbon appear to be two of these summits : They are
almost

almost entirely covered with matters rejected by volcano's. These two islands, when first discovered, were uninhabited.

In Guiana, our author remarks, the rivers are so near each other, and at the same time so swelled and rapid during the rainy season, that they carry down immense quantities of mud, and deposit them on all the low grounds and on the bottom of the sea. The coasts of French Guiana are so low, that they may rather be regarded as beaches totally covered with mud, and having an almost imperceptible declivity. This mud extends to a great distance at the bottom of the sea. Large vessels cannot approach the river Cayenne without striking; and ships of war are obliged to remain two or three leagues from the land. This mud extends along the whole margin of the sea from Cayenne to the river of the Amazonas. In this great extent of mud there is no sand, and berry-bearing alders are frequent all along the coast. But, seven or eight leagues above Cayenne, westward as far as the river Marony, we find some creeks, the bottoms of which consist of sand and rocks, which give rise to breakers. The mud, however, covers the greater part of these rocks, as well as the beds of sand; and it is thicker in proportion as it recedes from the margin of the sea. These small rocks prevent not the ground from

having a very gentle descent for several leagues on land. This part of Guiana, which, to the north-west of Cayenne, is more elevated than the lands to the south-east. Of this fact we have good evidence ; for all along the borders of the sea, we find large drowned savannahs, most of which are dry in the north-west, whilst they are totally covered with sea-water in the south-east parts. Beside these lands actually drowned by the sea, there are others more distant, which have likewise been formerly drowned. In some places we also find savannahs of fresh water ; but they produce no alders, but many palm-trees. On all these low coasts, not a stone is to be seen. The tide rises seven or eight feet, though it is opposed by the currents ; for they are all directed toward the Antilles. When the waters of the rivers are low, the tide is very perceptible, as high up the rivers as forty and even fifty leagues. But, during the rainy season, when the rivers are swelled, the tide is scarcely perceptible at the distance of a league or two, so great is the rapidity of the waters ; and their impetuosity is greatest during the reflux.

Upon the sandy bottoms of these creeks, the sea-turtles deposit their eggs ; and they never frequent the muddy places ; so that, from Cayenne to the river of the Amazonas, there are no turtles ; and the people go to fish them from the

the river Courou to the Marony. The mud appears to gain ground daily on the sand; and, in the progress of time, the north-west coast of Cayenne will be covered with it as well as the south-east; for the turtles, who will deposit their eggs in sand only, gradually retire from the river Courou; and, for some years past, the fishers are obliged to search for them near the river Marony, the sands of which are not yet covered.

Beyond the savannahs, some of which are dry and others drowned, there is a chain of hills that are all covered with a great depth of earth, and every where planted with forests. These hills are generally from 350 to 400 feet high. But, about ten or twelve leagues farther up the country, they are perhaps double this height. Most of these mountains are evidently extinguished volcano's. At the top of one of them, called *la Gabrielle*, there is a small lake, in which are a number of alligators, whose species seems to have been preserved from the time that the sea covered this hill.

Beyond Mount Gabrielle, we find only small valleys, little hills, and volcanic matters, not in large masses, but in small blocks. The most common stone, blocks of which are carried down by the waters as far as Cayenne, is that called *beetle-stone*. It is not a stone, but the lava of a volcano. It has received the name of *beetle-*

stone, because it is full of holes, which these insects inhabit.

Of the Glaciers.

In the highest regions of the Alps, the waters which proceed from the annual meltings of the snow, freeze in every direction, and on all the points of the mountains from their bases to their summits, and especially in the valleys, and on the declivities of those that are collected together in groups: In this manner, the waters have formed in these valleys some mountains which have rocks for their nucleus, and others that consist entirely of ice: These mountains are six, seven, and even eight leagues long by one in breadth, and often from a thousand, to twelve hundred fathoms high. These enormous masses of ice are continually extending farther along the valleys; for though, in warm and rainy seasons, their progress is not only stopped, but their size diminished, the magnitude of the glaciers is perpetually augmenting.

Under the equator, the point of congelation, in detached mountains, is fixed at the height of 2440 fathoms. But this is no rule for groups of mountains which are frozen from their summits to their base, and never thaw. In the Alps,
the

the point of congelation in detached mountains is ascertained to be at the height of 1500 fathoms, and all below this point thaws completely. But those which are grouped together freeze at a smaller height, and thaw from their top to their base; which shows how much the degree of cold is augmented by immense masses of congealed matter confined within a narrow compass.

The whole frozen mountains of Switzerland, when taken together, occupy an extent of 66 leagues from east to west, measured in a straight line from the western borders of the canton of Vallis towards Savoy, to the eastern borders of the canton of Bendner towards Tirol. They form an interrupted chain, several arms of which extend, from north to south, about 36 leagues. The great Gothard, the Fourk, and the Grimsel, are the highest mountains in this quarter: They occupy the center of those chains which divide Switzerland into two parts. They are perpetually covered with snow and ice; from which circumstance they have received the general denomination of *Glaciers*.

The glaciers are divided into frozen mountains, valleys of ice, fields of ice or frozen seas, and *glechers*, or heaps of icy flakes or plates.

The frozen mountains are those immense masses of rocks which reach the clouds, and are perpetually covered with ice and snow.

The

The valleys of ice are those depressions between the mountains which are much more elevated than the inhabited valleys. They are always filled with snow, which accumulates, and forms masses of ice several leagues in length. These masses join the high mountains.

The fields of ice, or frozen seas, which lie along the mountains, have a gentle declivity. They cannot be called valleys, because they are not sufficiently depressed. They are covered with a great thickness of snow. These fields receive water from the melting of the snow, which descends from the mountains, and afterwards freeze. The surface of these fields alternately melts and freezes; and the whole are covered with thick beds of snow and ice.

The glaciers are heaps of flakes or plates of ice formed by the snows, and precipitated from the mountains. These snows freeze again, and are interwoven in various manners: This circumstance has given rise to the division of glaciers into mounts, mantlings, and walls of ice.

The mounts of ice rise between the summits of the high mountains: They themselves form mountains; but they contain no rocks. They are composed entirely of ice, and are sometimes several leagues in length, one league broad, and half a league thick.

The mantlings are formed in the superior valleys, and upon the sides of the mountains, which

which are covered with ice, having folds resembling drapery: They send their superfluous waters into the lower valleys.

The walls of ice are rugged mantlings which terminate the flat valleys, and appear, at a distance, like troubled seas, whose waves have been suddenly arrested and frozen. These walls consist not of irregular points: They often form columns, pyramids, and enormous towers composed of several sides. These towers are sometimes hexagonal, and of a blue or greenish colour.

On the sides, and at the foot of the mountains, masses of snow are formed, which are afterwards moistened with the water from the melted snows, and then covered with fresh accumulations. We likewise see plates of ice collected in heaps, which belong neither to the frozen valleys nor the mountains of ice. Their position is either horizontal or inclined. These detached heaps are called *beds* or *strata* of ice.

Several of these mountains of ice are undermined by the interior heat of the earth, which gives rise to currents of water that melts their inferior surfaces. They then, by their own weight, sink insensibly, and their height is restored by the waters, snow, and ice, which again successively cover them. These sinkings often produce horrible crashings. The crevices which open in the ice form precipices which are both numerous and full of danger. These abysses

byffes are the more treacherous and baneful, because they are generally covered with snow. Travellers, and hunters who chase the fallow-deer, the chamois goat, &c. or those who search for crystals, are often swallowed up by these gulfs, and again thrown upon the surface by the waters which run at their bottoms.

Gentle rain quickly dissolves snows: But all the water which proceeds from them falls not into these gulfs. A great part of it freezes on the surface of the ice and augments its volume.

The warm south winds, which generally prevail in the month of May, are the most powerful agents in destroying the snows and ice. Their melting is announced by the crashing of the frozen lakes, and the dreadful noise produced by the shock of stones and ice, which in horrible confusion roll down from the tops of the mountains, and by torrents of water that fall from the rocks of more than 1200 feet high.

The heat of the sun has little effect upon the snow and ice. Experience has proved, that ice which has existed a long time under an enormous weight, and in accumulated degrees of cold, is so dense and so completely deprived of air, that, when small pieces of it are exposed to the greatest heat of the sun, during a whole day, they scarcely melt.

Though the glaciers melt partially every summer, though the winds and the heat of certain
years

years destroy the accumulation of several preceding years; yet it is certain, that these glaciers constantly augment in all their dimensions. This fact is ascertained by the annals of the country, by authentic deeds, and by invariable tradition. Independent of these authorities, and of daily observation, the progressive increase of the glaciers is proved by *forests of trees which have been absorbed by the ice, some of whose tops still appear above the surface of the glaciers*: These, as well as *the tops of steeples belonging to a village that had been buried under the snows, and which are still visible after uncommon meltings*, are irrefragable evidences of the gradual progress of the glaciers. This progression can proceed from no other cause than an augmentation in the degree of cold, which increases in proportion to the masses of accumulated ice. It is likewise certain, that, in the glaciers of Switzerland, the cold is at present more intense, though it continues shorter, than in Iceland, the glaciers of which, as well as those of Norway, have a great relation to those of Switzerland.

The substance of the frozen mountains of Switzerland is similar to that of all other high mountains. The nucleus is a vitreous rock which reaches to their summit. The parts below, which had been covered with the ocean, are composed of calcarious stone, as well as the whole

whole substance of the mountains of an inferior order, which are disposed in groups at the foot of the primitive glacier mountains. Lastly, these calcarious masses have slate, produced by the sediments of the waters, for their basis.

The vitreous masses are pure rock, granite, and quartz. Their fissures are filled with metals, semi-metals, mineral substances, and crystals.

The calcarious masses are lime-stone, marbles of every species, chalk, gypsum, spar, alabaster, &c.

The slaty masses consist of slates of various qualities and colours, which contain plants and fishes, and are often situated at considerable heights. Their strata are not always horizontal. They are often inclined, sometimes sinuated, and in particular places perpendicular.

We cannot entertain a doubt concerning the ancient abode of the sea upon the glacier mountains. The immense quantity of shells, as well as the slate and other similar stones, found in these mountains, fully ascertain this point. These shells are either distributed in tribes, or different species are blended together, and they are found at very great heights.

It is probable, that, at a very remote period, the glaciers had not been formed on these mountains, not even when the ocean abandoned them ; though it appears by their great distance
from

from the sea, which is near a hundred leagues, and by their excessive height, that they were the first that arose above the water in the Continent of Europe. They have likewise had their volcano's. Mount Myffenberg, in the canton of Schwitz, seems to have been the last volcano that was extinguished. The two principal summits, which are very high and detached, terminate in cones, like all the mouths of volcano's; and we still see the crater of one of these cones, which is very deep.

M. Bourrit, who had the courage to make a number of expeditions in the glaciers of Savoy, remarks, 'That the increase of all the glaciers in the Alps is unquestionable; that the quantity of snow that falls during the winters far surpasses that which melts in the summers; that the same cause not only subsists, but the masses of snow already formed must always augment, because this effect is a necessary result of that cause. Hence the glaciers must always continue to have a progressive increase *.'

The same indefatigable observer, when treating of the *glatchers* or glaciers with prominent points, says, 'that they appear to augment daily; that the ground they now occupy was some years ago a cultivated field; and that the ice still continues to augment †.' He relates, that

* Descript. des glaciers de Savoie, par M. Bourrit, p. 111.
112.

† Descript. des aspects du Mont Blanc, par le même, p. 8.

‘ that the growth of the ice is evident, not only in this place, but in several others ; that the inhabitants remembered a former communication between Chamounis and Val-d’Aost, which is now totally shut up by the ice ; that the ice, in general, must have first accumulated by stretching from summit to summit, and then from one valley to another ; and that, in this manner, a communication has been formed between the ice of Mount Blanc and those of the other mountains of Vallais, and of Switzerland *. It appears,’ says he, ‘ that all these mountainous countries were not anciently so much filled with ice and snow as they are at present It is only a few centuries since various calamities have been occasioned by the accumulation of snows and ice, in several valleys, and by the precipitation of mountains and rocks. It is only from these accidents, which are very frequent, and from the annual accumulations of the ice, that we are enabled to account for what history relates concerning the ancient inhabitants of this country†.’

* Descript. des aspects du Mont Blanc, par M. Bourrit, p. 13. et 14.

† Ibid. p. 62. et 63.

Of the North-East passage.

Notwithstanding what has been advanced by the Russians; it is extremely doubtful that they ever doubled the northern point of Asia. M. Engel, who regards the north-west passage by Hudson's and Baffin's bay, as impossible, appears, on the contrary, to be persuaded, that a shorter and more certain passage will be found by the north-east. To the feeble reasons he gives in support of this opinion, he adds a remark of M. Gmelin, who, when speaking of the experiments made by the Russians, in order to discover this north-east passage, says, 'that the manner in which they proceeded in making these discoveries will astonish the whole world, after an authentic relation of them shall be made public, which depends solely on the pleasure of the Empress.'—'There can be nothing astonishing,' says M. Engel, 'in this subject, except it be to learn that a passage, which was formerly regarded as impossible, is now found to be extremely practicable. This is the only fact,' he adds, 'which can surprise those whom the Russians have endeavoured to terrify by relations published for the purpose of repelling navigators from the attempt *,' &c.

* Hist. Gen. des Voyages, tom. 19. p. 415.

I shall, in the first place, remark, that we ought to be well ascertained with regard to facts, before we throw an imputation of this kind upon the Russian empire. In the second place, the remark seems to be ill founded ; for the words employed by M. Gmelin may admit of an opposite interpretation from that given of them by M. Engel, namely, That we will be astonished when we shall learn that no practicable passage exists by the north-east. Independent of the general reasons I have given, I am confirmed in this opinion by the following circumstance : The Russians themselves, in their late experiments, uniformly ascend by Kamptschatka, and never descend by the point of Asia. Captains Bering and Tschirikow, in the year 1741, reconnoitered the coast of America as far as the 59th degree ; but neither of them sailed northward along the coasts of Asia. This fact is a sufficient proof, that the passage is not so practicable as M. Engel supposes ; or rather, that the Russians are satisfied that it is not practicable ; for, if otherwise, their navigators would have been sent by this route, instead of making them take their departure from Kamptschatka, in order to discover the west of America.

M. Muller, who was sent by the Empress, along with M. Gmelin, to Siberia, is of a very different opinion from M. Engel. After comparing all the relations on this subject, M. Muller concludes

concludes by remarking, that there is only a very small separation between Asia and America; and that this strait contains several islands, which serve as common stations to the inhabitants of both continents. This opinion, I believe, is well founded; and, in support of it, M. Muller has collected a great number of facts. In the subterraneous abodes of the inhabitants of the island of Karaga, we see beams made of large pines, which neither this island, nor the adjacent countries of Kamtschatka, produce. The inhabitants say, that this wood is driven upon their coasts by the east wind. On the coasts of Kamtschatka, boards of ice are driven, for several days together, during the winter. At certain seasons, flights of birds arrive, and, after staying some months, return to the east, from whence they came. Hence the continent opposite to that of Asia, toward the north, descends as far as Kamtschatka. This continent must be the west of America. M. Muller *, after giving an abridgement of five or six voyages attempted by the north sea, with a view to double the north point of Asia, concludes, that every circumstance announces the impossibility of this navigation, which he proves by the following arguments. This navigation must be performed in summer: The distance from Archangel to the Oby, and from

VOL. IX.

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* Hist. Gen. des Voyages, tom. 18. p. 484.

this river to Jenisey, requires a whole season. The passage by Waygait has cost infinite labour to the British and Dutch. In going through this icy strait, we meet with islands which block up the road ; and the continent, which forms a cape between the rivers Piasida and Chatanga, and advances beyond the 76th degree of latitude, is likewise bordered with a chain of islands, which scarcely leave a passage for navigation. If we want to remove from the coasts, and to reach the open sea toward the Pole, the almost immoveable mountains of ice found at Greenland and Spitzbergen, seem to indicate a continuity of ice as far as the Pole. If we want to go along the coasts, *this navigation is more difficult now than it was a hundred years ago.* There the waters of the ocean are sensibly diminished : We still see, at a distance from the shoals along the Frozen Sea, wood that had been thrown upon the lands which formerly bounded the ocean. These shoals have so little depth, that very flat boats can alone be used in them : such boats are too weak to resist the ice ; neither can they contain provisions sufficient for a long navigation. Though the Russians have resources for sailing these cold seas superior to those of most other European nations, yet in none of the voyages attempted upon the Frozen Sea has a passage been discovered between Europe or Asia to America. It is only by departing from
Kamtschatka,

Kamtschatka, or some other more easterly point of Asia, that the westerly coasts of America have ever been discovered.

Captain Bering took his departure from port Awatscha in Kamtschatka, on the 4th day of June 1741. After sailing south-east, and then north-east, he discovered, on the 18th of July, the continent of America in latitude $58^{\circ} 28'$. Two days after, he anchored near an island in the mouth of a bay, from whence he discovered two capes, the one to the east he called Saint-Elie, and the other to the west Saint-Hermogene. He then dispatched Chitrou, one of his officers, to reconnoitre the gulf which he had entered: They found that it was interspersed with islands, on one of which they saw deserted cabins made of planks well joined, and even chamfered. They conjectured that this island might have been inhabited by some people from the continent of America. M. Steller, who was sent to make observations on these new discovered lands, found a cave, in which were a quantity of smoked salmon, ropes, furniture, and other utensils. Advancing still farther, he saw the Americans flying from him. He next perceived a fire on a distant hill. The savages had unquestionably retired thither: A rugged and steep rock covered their retreat *.

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* Hist. Gen. des Voyages, tom. 19. p. 371.

After relating these facts, it is easy to perceive, that it is only by taking their departure from Kamtschatka that the Russians can carry on commerce with China and Japan, and that it is equally difficult, if not impossible, for the other nations of Europe to pass by the north-east seas, the greater part of which are entirely frozen. Hence I cannot hesitate in repeating, that the only possible passage is by the north-west, at the bottom of Hudson's bay, and that this is the place where all future attempts to discover this useful passage ought to be made.

After the preceding sheets had been printed, I received from M. le Comte Schouvaloff, that great statesman whom all Europe esteems and respects, an excellent memoir composed by M. de Domascheneff, president of the Imperial Society of Petersburg, and to whom the Empress has assigned the department of every thing relating to arts and sciences. This illustrious person has likewise sent me a copy of the chart drawn by the pilot Otcheredin, in which are represented the tracks and discoveries he made in the years 1770 and 1773, between Kamtschatka and the continent of America. M. de Domascheneff, in his memoir, remarks, that this chart of the pilot Otcheredin is most exact, and that the one published in the year 1773 by the Academy of Petersburg, requires several amendments, especially with regard to the position

tion of the islands and the pretended Archipelago, which are represented between the Aleutes or Aleoutes islands, and those of Anadir, otherwise called Andrien. The chart of Otcheredin seems to show, that these two groups of islands, the Aleutes and the islands of Andrien, are separated by an open sea of more than a hundred leagues broad. M. de Domascheneff assures us, that the great general chart of the Russian empire, published in the year 1777, gives an accurate representation of all the coasts on the northern extremity of Asia inhabited by the Tschut-chis: He says, that this chart was executed from the most recent discoveries made in the last expedition of Major Pawluzki against that people. 'This coast,' says M. de Domascheneff, 'bounds the great chain of mountains which separate Siberia from the south of Asia, and terminates by dividing itself between the chain that stretches through Kamtschatka, and those which occupy the territories between the rivers that run to the east of the Lena. The known islands between the coasts of Kamtschatka and those of America are mountainous, as well as the coasts of Kamtschatka and those of the continent of America. Hence there is a distinct continuation between the chains of mountains belonging to both continents, the intervals of which, perhaps less considerable formerly, may have been enlarged by the decaying of rocks,

‘ by the perpetual currents which run from the
 ‘ Frozen Sea toward the southern ocean, and by
 ‘ the revolutions which the earth has undergone.’

But this sub-marine chain which joins the lands of Kamtschatka to those of America is more southerly, by seven or eight degrees, than that of the islands of Anadir or Andrien, which, from time immemorial, have served the Tschutschis as a passage to America.

According to M. de Domascheneff, it is certain, that this voyage from the point of Asia to the continent of America, is performed by oars, and that these people go there to dispose of Russian iron-works to the Americans; that the islands in this passage are so frequent, that the sailors may sleep every night on land; and that the continent of America, with which the Tschutschis traffick, is mountainous, and covered with forests, which are full of foxes, martins, and sables, the qualities and colours of whose furs are totally different from those of Siberia. These northern islands, situated between the two continents, are known to the Tschutschis only. They form a chain between the most eastern point of Asia and the continent of America, under the 64th degree of latitude; and this chain is divided by an open sea, from the other more southern chain formerly mentioned, which lies between Kamtschatka and America, and is under the 56th degree. The islands of this second chain

the

the Russians and inhabitants of Kamtschatka frequent in quest of sea-otters, and black foxes, whose furs are very precious. Before the year 1750, even the most eastern of the islands which compose this chain were known. One of these islands bears the name of Captain Bering, and another, adjacent to the former, is called the island of Medenoi. We next meet with the islands of Aleutes or Aleoutes. The two first are situated a little above, and the last a little below the 55th degree of latitude. About the 56th degree, we find the islands of Atkhon and Amlaigh, which are the first of the chain called the Islands of Foxes: They extend as far to the north-east as the 61st degree of latitude. These islands have received their denomination from the prodigious number of foxes found in them. The two islands of Captain Bering and Medenoi were uninhabited when first discovered. But, in the islands of Aleutes, though advanced farther to the east, more than sixty families were found, whose language had no relation either to that of Kamtschatka or to any of the oriental languages of Asia: It is a dialogue of the language spoken in the other islands adjacent to America, which seems to indicate that they have been peopled by the Americans, and not by the Asiatics.

The islands called by Captain Bering's crew Saint-Julian, Saint-Theodor, and Saint-Abraham,

ham, are the same with those which now receive the name of Aleutes. In the same manner, the islands of Chommaghin and Saint-Dolmat, discovered by this navigator, form a part of those now called the Islands of Foxes.

‘ The great distance,’ says M. de Domascheneff, ‘ and the open and deep sea between the
 ‘ islands of Aleutes and those of Foxes, joined
 ‘ to the different direction of the latter, render
 ‘ it probable, that these islands never formed one
 ‘ continued chain, but that the former, with
 ‘ those of Medenoi and Bering, make a chain
 ‘ which comes from Kamtschatka; that the
 ‘ Islands of Foxes exhibit another passage to
 ‘ America; and that both of these chains generally
 ‘ lose themselves in the depth of the ocean, and
 ‘ are promontories to the two continents. The
 ‘ course of the Islands of Foxes, some of which
 ‘ are of great extent, is intermixed with rocks
 ‘ and breakers, and continues without interruption
 ‘ as far as the continent of America. But
 ‘ those most adjacent to this continent are very
 ‘ little frequented by the Russian hunters; because
 ‘ they are very populous, and it would be
 ‘ dangerous to sojourn in them. There are several
 ‘ islands in the neighbourhood of America
 ‘ which are still little known. Some ships, however,
 ‘ have penetrated as far as the island of
 ‘ Kadjack, which is very near the continent
 ‘ of America. We are assured of this fact by the
 ‘ relation

' relation of the islanders ; and other circum-
 ' stances confirm the truth of their assertion : All
 ' the islands that lie more to the west, produce
 ' only dwarfish and mis-shapen shrubs, which
 ' the winds from the open sea prevent from ri-
 ' sing higher. The island of Kadjack, on the con-
 ' trary, and the small adjacent islands, produce
 ' groves of alder-trees, which seem to indicate
 ' that they are less exposed, and that they are
 ' sheltered on the north and east by a neigh-
 ' bouring continent. Besides, in Kadjack, we
 ' find fresh water otters, which appear not
 ' in the other islands ; and we likewise find a
 ' small species of marmot, which seems to be the
 ' marmot of Canada. Lastly, we discover, in
 ' that island, traces of the bear and wolf ; and
 ' the inhabitants clothe themselves with rain-
 ' deers skins brought to them from the conti-
 ' nent of America, to which they lie very con-
 ' tiguous.

' From a voyage to the island of Kadjack, con-
 ' ducted by one Geottos, we learn, that the con-
 ' tinent of America is called *Atakthan* by the
 ' islanders : They say, that this great land is
 ' mountainous and covered with forests ; that
 ' it is situated to the north of their island ; and
 ' that the mouth of a great river there goes by
 ' the name of *Alaghschak*. Besides, it is un-
 ' questionable, that Bering, as well as Tschiri-
 ' kow, actually reached this great continent ;
 ' ' for,

' for, at Cape Elie, where Bering moored his
' frigate, they saw the coast rise into a chain
' of mountains which were covered with thick
' forests. The soil was of a nature totally dif-
' ferent from that of Kamtschatka ; and Steller
' collected a number of American plants.'

M. de Domascheneff farther observes, that all the
Islands of Foxes, as well as those of Aleutes
and Bering, are mountainous ; that their coasts
are rocky, often terminate in precipices, and
are surrounded to a considerable distance with
rocks ; that the country rises, from the coasts
to the middle of these islands, into rugged
mountains, which form small chains through
the whole length of each island. Besides, there
have been, and still are, volcano's in several of
these islands ; and in those where the volcano's
are extinguished, there are fountains of hot
water. In the islands with the volcano's, no
metals are found, but only calcedons and
some other coloured stones of no value. In these
islands, the inhabitants have no other wood but
what is floated into them by the sea, and the
quantity is not great. More wood arrives in
the island of Bering and the Aleutes. This
floated wood seems to come from the south ;
for the camphor tree of Japan has been found
on the coasts of these islands.

The inhabitants are pretty numerous ; but, as
they lead a wandering life, and transport them-
selves

selves from one island to another, it is not possible to ascertain their number. It has been remarked, in general, that the larger the islands are, they are the nearer America, and the more populous. It likewise appears, that all the inhabitants of the islands of Foxes are of the same nation, to which those of the Aleutes and the islands of Andrien may also be referred, though they differ in some customs. All these people, in their manners, modes of living, and of feeding, have a great resemblance to the Esquimaux and the Greenlanders. *Kanaghist*, the name of these islanders in their own language, and perhaps corrupted by the mariners, has still a great affinity to *Karalit*, the denomination of the Esquimaux and their brethren the Greenlanders. Among the inhabitants of all the islands between Asia and America, no other utensils were found but stone-hatchets, flint-knives, and the shoulder bones of animals sharpened to cut herbage. They have likewise darts armed with sharp flints, and most artfully cut. They have now a great many implements of iron, which they have obtained from the Russians. They make canoes like the Esquimaux; some of them are so large that they contain twenty persons. They are made of light wood, and are entirely covered with the skins of seals and other sea-animals.

From all these facts, it appears, that, from
time

time immemorial, the Tschutschis, who inhabit the eastern point of Asia between the 55th and 70th degree of latitude, have had commerce with the Americans ; that this intercourse was the more easy to a people accustomed to all the rigours of cold ; and that the voyage, which perhaps exceeds not a hundred leagues, might be performed in simple canoes, conducted by oars in summer, and probably on the ice in winter, by landing daily upon a different island. America, therefore, might be peopled by Asia under this parallel ; and every circumstance seems to indicate, that, though there are now intervals of sea between these islands, they formerly constituted but one continent, by which America was joined to Asia. It is likewise probable, that, beyond the islands of Anadir or Andrien, *i. e.* between the 70th and 75th degree of latitude, the two continents are absolutely united, though that track of land is perhaps entirely covered with snow and ice. To explore the regions beyond the 70th degree is an enterprize worthy of the great Sovereign of the Russias, and it ought to be entrusted to a navigator equally intrepid as Captain Phipps. I am persuaded, that they would find the two continents united ; but, if otherwise, and if there is an open sea beyond the islands of Andrien, it appears to be certain, that they would find the projections of the great Polar glacier at the 81st
or

or 8d degree, as Captain Phipps discovered them at the same latitude between Spitzbergen and Greenland.

Concerning that period when the powers of Man aided those of Nature.

The first men were witnesses of the convulsive motions of the earth, which were then frequent and terrible. For a refuge against inundations, they had nothing but the mountains, which they were often forced to abandon by the fire of volcano's. They trembled on ground which trembled under their feet. Naked in mind as well as in body, exposed to the injuries of every element, victims to the rapacity of ferocious animals, which they were unable to combat, penetrated with the common sentiment of terror, and pressed by necessity, they must have quickly associated, at first to protect themselves by their numbers, and then to afford mutual aid to each other in forming habitations and weapons of defence. They began with sharpening into the figure of axes those hard flints, those *thunder-stones*, which their descendants imagined to have been produced by thunder, and to have fallen from the clouds, but which, in reality, are the first monuments of human art. They would soon extract fire from these flints by striking them against each other.

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To destroy the brushwood and the forests, they would employ the flames derived from volcano's, or from their burning lavas; for, with the assistance of this powerful element, they cleared and purified the grounds which they chose to inhabit. With the axes of stone, they cut trees, and fabricated those weapons and utensils of which necessity first suggested the use; and, after being provided with clubs and other heavy armour, would not these first men discover the means of making lighter weapons to annoy at a distance? The tendon of an animal, the fibres of aloes, or the pliant bark of some ligneous plant, would serve them for a cord to unite the extremities of an elastic branch; with which they made their bow: To arm their arrows, they employed small sharp flints. In a short time they would have thread, rafts, and canoes; and in this state they would remain till little nations were formed. These nations were composed of a few families, or rather of the descendants of the same family, which is still the condition of those savages who live independent in such open and spacious territories as afford them game, fishes, and fruits. But, in territories which are narrowed by waters, or confined by high mountains, these small nations, after a great increase of population, were obliged to divide the land among themselves; and, from this moment, the earth became the inheritance of man. He
took

took possession of it by his labour and cultivation; and the attachment to a native soil followed rapidly the first acts of property. As individual interest constitutes a part of national order, government and laws must have succeeded, and society must have assumed strength and consistence.

Nevertheless, these men, deeply affected with the miseries of their original state, and having still before their eyes the ravages of inundations, the conflagrations of volcano's, and gulfs opened by the succussions of the earth, have preserved a durable, and almost eternal, remembrance of the calamities the world has suffered. The idea, that it must perish by an universal deluge, or by a general conflagration; the reverence for certain mountains upon which they had been saved from inundations; their horror at others which threw out fires more dreadful than those of thunder; the view of those combats between the earth and heavens, which gave rise to the fable of the Titans, and of their assaults against the Gods; the notion of the real existence of a malevolent being, with the terror and superstition which it unavoidably produced; all these sentiments, founded upon fear, took an unconquerable possession of the human mind. Even at present, men are not entirely emancipated from these superstitious terrors by the experience of time, by the tranquillity which succeeded

ceeded those ages of convulsions and storms, nor by the knowledge of the effects and operations of Nature, a knowledge which could not be acquired till after the establishment of some great society in a tranquil land.

It is neither in Africa, nor in the most southern regions of Asia, that great societies or nations could be first formed. These countries were still burning and desert. Neither could this event happen in America, which, except its chain of mountains, is evidently a new country; nor even in Europe, which very lately derived its learning from the East, where the first civilized men were established; for, before the foundation of Rome, the happiest countries in this part of the world, such as Italy, France, and Germany, were then peopled with men more than half savage. Tacitus, in his Manners of the Germans, exhibits a picture of those of the Hurons, or rather of men just emerging from a state of nature. Hence the source of human knowledge must have arisen in the northern countries of Asia; and power is a necessary result of knowledge. The more man knows, the more he can perform; and the less he has done, the less he knows. All this implies an active people in a happy climate, living under a pure sky and in a fertile country, remote from inundations and volcano's: It must also have been a high country, and, of course, more anciently temperate than

than the more southern regions. Now, all these conditions, all these circumstances, are united in the centre of Asia, from the 40th to the 55th degree of latitude. The rivers which run into the North Sea, into the Eastern Ocean, and into the South and Caspian Seas, take their rise from this elevated region, which at present composes the southern part of Siberia and of Tartary. It is, therefore, in this country, which is more elevated than all the others, since it serves them as a centre, and is near five hundred leagues from any ocean; it is in this privileged country that the first people worthy of notice were produced; and they merit our esteem as the inventors of arts, sciences, and every useful institution. This truth is equally evident from the monuments of natural history, and from the almost inconceivable progress of astronomy. How could men so new invent the lunisolar period of six hundred years? I confine myself to this single fact, though many others equally wonderful and permanent might be produced. These people, therefore, knew as much of astronomy as was known in the days of Cassini, who first demonstrated the reality and exactness of this period of six hundred years; a knowledge of which the Chaldeans, Egyptians, and Greeks, were perfectly ignorant; a knowledge which presupposes that of the exact movements of the earth and moon, and requires great perfection in

the instruments necessary to make observations ; a knowledge, which, as it implies the acquisition of every thing derived from a long succession of astronomical study and research, must have required at least two or three thousand years exertion of the human mind.

These first people, because they had become very learned, must have been proportionally happy. They must have enjoyed many ages of peace and leisure, which are necessary for the cultivation of science. Before they could entertain a suspicion concerning the period of six hundred years, at least twelve hundred years of astronomical observations were requisite ; and, to ascertain the fact, more than double that number of years were necessary. Thus we have already about three thousand years employed in astronomical studies : Neither should this circumstance surprise us ; for, in reckoning from the Chaldean astronomers to the present day, an equal time has been employed in discovering this period of six hundred years. Besides, these three thousand years of astronomical observations must necessarily have been preceded by many ages in which science was unknown. Nay, are six thousand years from the present time sufficient to discover the most noble epoch in the history of man, or even to trace his gradual progress in the arts and sciences ?

But, unhappily these sublime and beautiful
sciences

Sciences are lost : We can only recognise their past existence by deformed and imperfect fragments. The invention of the *formula* by which the Brahmins calculate eclipses, presupposes as much science as the construction of our Ephemerides ; and yet these Brahmins have not the smallest idea of the structure of the universe. They possess only some false notions concerning the motion, magnitude, and position of the planets. They calculate eclipses without knowing the theory of them. This operation they are enabled to perform by machines or tables founded upon learned formulae, which they do not comprehend, and which, probably, were not invented by their ancestors ; because they have never brought any thing to perfection, and have not transmitted the smallest ray of science to their descendants. In their hands, these formulae are only practical methods ; but they imply profound knowledge, of which these people have not preserved the slightest vestige, and which, of course, they have never possessed. Hence these methods could only proceed from that ancient people, who had reduced into formulae the motion of the stars, and who, by a long course of observations, could not only predict eclipses, but, what is much more difficult, they recognised the period of six hundred years, and, of course, were acquainted with all

those astronomical facts which this discovery necessarily required.

I may affirm, that the Brahmins never invented these formulae ; because all their physical ideas are contrary to the theory on which these formulae depend. If they had comprehended this theory, even at the time they received its results, the science would have been preserved, and they would not, as they do at present, have entertained the most absurd and ignorant notions concerning the system of the universe ; for they believe that the earth is immoveable, and is supported by a mountain of gold ; that the moon is eclipsed by aerial dragons ; that the planets are smaller than the moon, &c. It is therefore evident, that they never had the first elements of astronomical theory, nor the smallest knowledge of the principles upon which the methods they employ depend *.

The Chinese, who are a little more enlightened than the Brahmins, calculate eclipses in a very rude manner, and they have continued to calculate them in the same manner for two or three thousand years. As they bring nothing to perfection, they can never invent. Hence science neither originated in China nor in India. Though equally near as the Indians to the first learned people,

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* For a more complete view of this subject, I refer the reader to an excellent account of ancient astronomy lately published by Bailly, whose ideas perfectly coincide with mine.

the Chinese appear not to have derived any advantage from this favourable situation. They are not even possessed of those astronomical formulae of which the Brahmins have preserved the use, and which constitute the first great monuments of the knowledge and happiness of man. Neither does it appear that the Chaldeans, Persians, Egyptians, or Greeks, received any advantage from this first enlightened race of men ; for, in these Levant countries, the new astronomy must be ascribed to the indefatigable assiduity of the Chaldean observers, and afterwards to the labour of the Greeks, which can only be dated from the foundation of the Alexandrian school. This science, however, after the culture of two thousand years, and even till these two or three last centuries, was very imperfect. It seems, therefore, to be certain, that these people, who first invented, and for a long succession of ages so happily cultivated astronomy, have left nothing but some fragments, some results of the science, which might be retained in the memory, such as that of the period of six hundred years, which has been transmitted to us by Josephus the Jewish historian, who did not understand its value or import.

The loss of the sciences, that first wound to humanity inflicted by the sword of barbarity, must have been the effect of some direful revolution, which, in a few years perhaps, destroyed

the labours and the ingenuity of many ages; for those first powerful and learned people must have continued long in a state of splendour and prosperity, since they made so great progress in the sciences, and, of course, in all the arts which the study of them necessarily require. But it is extremely probable, that, when the regions to the north of this happy country, had become too cold, their inhabitants, still ignorant, ferocious, and barbarous, would pour in upon this rich and cultivated country. It is even astonishing, that these barbarians should have been able to annihilate not only the principles, but the remembrance of all science. Three thousand years of ignorance, perhaps, followed the three thousand years of light and knowledge which had preceded them. Of all these first and beautiful fruits of the human genius, there now remains nothing but a metaphysical religion, which, being incomprehensible, required no study, and could neither be altered nor lost but by a defect of memory, which never fails when it is struck with the marvellous. From this first centre of the Sciences, the same metaphysical religion diffused itself over every quarter of the globe. The idols of Calicut are the same with those of Seleginskoi. Pilgrimages to the great Lama are undertaken at the distance of more than two thousand leagues. The idea of the metempsychosis, or transmigration of souls, extends

tends still farther, and is adopted as an article of faith by the Indians, the Æthiopians, and the Atlantes. The same notions, a little disguised, were received by the Chinese, Persians, Greeks, and Romans. Every circumstance concurs in proving, that the first common stem of human knowledge arose in this region of Asia *, and that its barren or degenerated branches extended into every part of the earth.

The past ages of barbarity are for ever buried in profound darkness. Men were then so deformed with ignorance, that human nature was hardly recognisable: For rudeness, followed by the neglect of duty, began to relax the bonds of society, which were afterwards torn asunder by barbarity; the laws were despised or proscribed; manners degenerated into habits of ferocity; the love of society, though engraven on the human heart, was totally effaced; in a word, man, without education, without morals, was reduced to lead a solitary and savage life, and, instead of the high dignity of his nature, presented the picture of a being degraded below the brutes.

However,

* The learned M. Pallas remarks, that the cultivation, the arts, and the towns thinly scattered through this region, are living monuments of an empire or flourishing society; whose history is buried with its cities, temples, and arms, of which enormous ruins are daily dug out of the earth. These scattered people are the members of a great nation, which has no head. *Voyage de Pallas en Siberie.*

However, after the loss of the sciences, the useful arts to which they had given birth were preserved. The cultivation of the earth, which became more necessary in proportion to the increase of population; all the arts and practices which this culture requires, as well as all those employed in the construction of buildings, in the fabrication of idols and arms, in the weaving of stuffs, &c. survived the sciences. These arts were gradually diffused and brought to perfection: They followed the course of population. The ancient empire of China first arose, and nearly at the same time that of the Atlantes in Africa. The empires on the continent of Asia, those of Egypt and Æthiopia, were successively established, and, lastly, that of Rome, to which our Europe owes its civil existence. Hence, about three thousand years only have elapsed since the power of man united with that of Nature, and spread over the greatest part of the earth. Before this period, the treasures of fertility were buried. The other resources of man, still more profoundly interred, could not elude his researches, but have become the reward of his labours. When he conducted himself with wisdom, he followed the lessons of Nature; he derived advantage from her examples; he employed her means, and, from the immensity of her productions, selected all those objects from which he could derive either utility or pleasure.

By

By his intelligence the animals were subdued, tamed, and reduced to perpetual slavery. By his labours, the marshes were drained, the rivers were restrained, and their cataracts effaced, the forests were cleared, and the earth cultivated. By his reflection, times were computed, spaces were measured, the celestial motions were recognised, combined, and represented, the heavens and the earth were compared, the universe was augmented, and the Creator worthily adored. By his art, which is an emanation of science, the seas have been traversed, and the mountains overcome; nations have been united; a new world has been discovered; a thousand other detached lands have been reduced under his dominion; lastly, the whole face of the earth at present exhibits the marks of his power, which, though subordinate to that of Nature, often exceeds, at least, so wonderfully seconds her operations, that, by the aid of his hands, her whole extent is unfolded, and she has gradually arrived at that point of perfection and magnificence in which we now behold her.

Compare rude with cultivated Nature. Compare the small savage nations of America with those of our civilised people, or even with those of Africa, who are only half cultivated. Contemplate the condition of the lands which those nations inhabit, and you will easily perceive the insignificance of men who have made

so

so little impresson on their native soil. Whether from stupidity or indolence, these brutish men, these unpolished nations, great or small, give no support to the Earth; they starve without fertilizing her; they devour every thing, and propagate nothing. The savage state, however, is not the most despicable condition of mankind, but that of those nations who have just begun to be polished, who have always been the real scourges of human nature, and who, even at present, can hardly be restrained by the people who are completely civilised. They have, as formerly remarked, ravaged the first happy land. They have torn up the germs of happiness, and destroyed the fruits of science. How many invasions have succeeded this first irruption of barbarians? From these same northern regions, where every human virtue formerly existed, all our evils afterwards proceeded. How often have we seen these irruptions of animals with human faces, who always come from the north, ravage the countries of the south? Consult the annals of all nations, and you will find twenty ages of desolation, for a few years of ease and tranquillity.

Nature required six hundred ages to construct her great works, to temper the earth, to fashion its surface, and to arrive at repose: How many ages would men require before they ceased to disturb and destroy each other? When will they learn,

learn, that the peaceable possession of their own country is sufficient for their happiness? When will they be wise enough to give up their false pretensions, to renounce imaginary dominions, and distant possessions, which are often ruinous, or at least cost more than their value? The Spanish empire in Europe is as extensive as that of France, and ten times larger in America; Is it ten times more powerful? Is it even as powerful as if this bold and great nation were limited to derive from its own happy country all the benefits which it could furnish? Have not the British, a people so sensible, and such profound thinkers, committed a great error by extending too far the limits of their colonies? The ancients appear to have had more correct ideas with regard to these establishments. They never projected emigrations till their population was too great, and their territory and commerce were not sufficient to supply their wants. Have not the invasions of barbarians, which we look upon with horror, had causes still more pressing, when they found themselves too numerous in ungrateful, cold, and naked countries, and at the same time surrounded with fertile and cultivated lands, which produced every article they required? But, what quantities of blood, what calamities, what losses, have accompanied and followed these direful conquests?

We shall dwell no longer on the dismal spectacle of those revolutions of death and devastation,

tion, which are the genuine effects of ignorance. Let us entertain the agreeable hopes, that the balance, though imperfect, which subsists between cultivated nations, will continue, and become even more stable in proportion as men shall have better notions of their real interest; that they will learn the value of peace and tranquil happiness; that the acquisition of this object will be the chief aim of their ambition; and that Princes will disdain the false glory of conquerors, and despise the little restless vanity of those who excite them to such dreadful commotions.

Let us suppose the world in peace, and take a nearer prospect of the influence of man's power over that of Nature. Nothing appears to be more difficult, not to say impossible, than to oppose the successive cooling of the earth, and to warm the temperature of a climate; yet this feat man can and has performed. Paris and Quebeck are nearly under the same degree of latitude; Paris, therefore, would be as cold as Quebeck, if France and the adjacent countries were as thinly inhabited, and as much covered with wood and water as the territories in the neighbourhood of Canada. The draining, clearing, and peopling a country, will give it a warmth which will continue for some thousand years; and this fact will prevent the only reasonable

sonable objection which can be made against my opinion, that the earth is gradually cooling.

According to your system, it may be said, the whole earth must be cooler now than it was two thousand year ago: But tradition proves the contrary. France and Germany formerly produced rain-deer, lynxes, bears, and other animals which have since retired to more northerly regions. This progress is very different from what you maintain, namely, from north to south. Besides, history informs us, that the river Seine was annually frozen during a part of the winter. Are not these facts a direct contradiction to the gradual cooling of the earth? They would, I acknowledge, if France and Germany were now in the same state; if we had not cut down the forests, drained the marshes, confined the torrents, directed the rivers, and cleared all the lands which were overgrown with unprofitable plants. But we ought to consider, that the heat of the globe diminishes in an imperceptible manner; that seventy-two thousand years were necessary to cool it to a proper temperature, and that an equal portion of time must elapse before it is so cold as to be unfit for the nourishment of animals and vegetables. We must consider the difference between this slow cooling of the earth and the sudden colds produced in the atmosphere; and we must nevertheless recollect, that the difference

ence between the greatest heat of our summers, and the greatest cold of our winters, exceeds not a thirty-second part. From these considerations it is apparent, that external causes have a much greater influence upon the temperature of every climate than the internal cause, and that, in all those climates where the cold of the superior regions of the air is attracted by moisture, or pushed by the winds towards the surface, the effects of these particular causes are much more powerful than that produced by the general cause. Of this we shall give an example, which will remove every doubt, and at the same time obviate every similar objection.

In the immense territories of Guiana, which are covered with thick forests, where the sun can hardly penetrate, where great tracts of country are overflowed with water, where the rivers are very near each other, and are neither restrained nor directed, where it rains continually during eight months of the year, the inhabitants, about a century ago, began to clear the country arround Cayenne, which is a very small canton of these vast forests. The difference of temperature in this little district is already so perceptible, that the people are too warm during the night ; but, in all the lands which are covered with wood, the nights are so cold that fires are necessary in the houses. The same effect is produced with regard to the quantity and duration

tion of the rains : They cease sooner and commence later at Cayenne than in the interior parts of the country ; neither are they so heavy, nor so frequent. At Cayenne, there are four months of absolute driness : But, in the interior parts of the country, the dry season lasts only three months ; besides, a daily rain is brought down by the south winds, which is pretty violent. Another circumstance merits attention : It seldom thunders at Cayenne ; but, in the interior parts, where the clouds are black, thick, and very low, the thunder is violent and very frequent. These facts show, in the clearest manner, that, in this country, the eight months of perpetual rain might be diminished, and the heat greatly augmented, if the forests were cut down, if the waters were restrained, and the rivers properly directed, and if the cultivation of the earth, which supposes the movements of a great number of men and animals, banished that cold and superfluous moisture which is attracted and diffused by the immense quantity of vegetables.

As every action, every movement, produces heat, and as all beings endowed with the faculty of progressive motion, may be considered as so many little fires, it is in proportion to the number of men and animals, that (every thing else being equal) the local temperature of each particular country depends. The former diffuse heat, the latter nothing but cold and moisture. The perpetual use men make of fire adds greatly to
the

the artificial temperature of all populous territories. In Paris, during great colds, the thermometers at the Faubourg Saint-Honoré stand two or three degrees lower than those at the Faubourg Saint-Mercean; because the north wind is heated in passing over the numerous chimneys of that great city. A single forest in any country is sufficient to produce some change in its temperature. Trees attract the cold; by their shade they diminish the heat of the sun; they produce moist vapours that form clouds and fall down in rain, which is always colder from the greater height it descends. When these forests are abandoned to Nature alone, the old trees fall and coldly corrupt; but, when under the dominion of man, they are used as fuel to the element of fire, and become the secondary causes of every particular heat. In meadows, before the herbage is cut down, there are always copious dews, and often small showers of rain, which cease as soon as the grass is carried off. These small rains would become more abundant and more durable, if our meadows, like the savannahs of America, were always covered with the same quantity of herbs, which, instead of diminishing, must increase by the accumulating manner of all those that die and corrupt on the surface.

Many other examples might be given, all concurring to show that man can have an influence

fluence on the climate he inhabits, and, in a manner, fix its temperature at any point that may be agreeable to him; and, what is singular, it is more difficult for him to cool than to heat the earth. He is master of the element of fire, which he can augment and propagate at pleasure, but not of the element of cold, which he can neither lay hold of nor communicate. The principle of cold is not a real substance, but a simple privation, or rather diminution of heat; a diminution which ought to be very great in the high regions of the air, and which, at the distance of a league from the earth, converts the aqueous vapours into hail and snow. For the emanations of the heat proper to the globe observe the same law as all other physical quantities or qualities which proceed from a common centre; and, as their intensity decreases in the inverse ratio of the square of the distance, it appears to be certain, that the atmosphere is four times colder at the height of two leagues than at that of one; each point of the earth's surface being considered as a centre. On the other hand, the interior heat of the globe, in every season, is constantly ten degrees above the freezing point. Hence the earth can never be colder than ten degrees above this point, except by the fall of cold matters upon its surface from the superior regions of the air, where the effects of the internal heat of the globe diminish in pro-

portion to the height. Now, the power of man extends not so far. He cannot make cold descend, as he makes heat ascend. He has no other mode of defending himself from the ardour of the sun's rays, but by forming a shade. But it is more easy to cut down the forests of Guiana, in order to heat the humid earth, than to plant trees in Arabia to refresh the burning sands. A single forest, however, in the midst of these parched deserts, would be sufficient to render them more temperate, to attract the waters from the atmosphere, to restore all the principles of fertility to the earth, and, of course, to make man, in these barren regions, enjoy all the sweets of a temperate climate.

It is upon the difference of temperature that the stronger or weaker energies of Nature depend. The growth, and even the production, of all organized beings, are only particular effects of this general cause: Hence man, by modifying this cause, may in time destroy what injures him, and give birth to every thing that is agreeable to his feelings. Happy are those countries where all the elements of temperature are balanced, and so fortunately combined as to produce only good effects! But, has any country, from its origin, ever enjoyed this privilege? Is there any country where the power of man has not aided that of Nature, either by attracting or dissipating the waters, by destroy-
ing

ing noxious or superfluous vegetables, and by taming and multiplying useful animals? Of three hundred species of quadrupeds, and fifteen hundred species of birds, man has selected nineteen or twenty*; and these twenty species make a greater figure in Nature, and are more useful to the earth than all the others: They make a greater figure, because they are directed and prodigiously multiplied by man. By co-operating with him, they produce all the benefits which could be expected from a wise distribution of powers in cultivating the earth, in transporting the articles of commerce, in augmenting provisions, in supplying all the wants, and in ministering to the pleasures of their only master who can reward their services by his industry and attention.

Of the small number of animals selected by man, the hen and the hog species, which are the most prolific, are likewise the most generally diffused, as if the aptitude for great multiplication were accompanied with that vigour of constitution which braves every danger or inconvenience arising from difference of climate. The hen and the hog have been found in the most unfrequented regions of the earth, in Otaheite and other southern islands, which are the most

C c 2 remote

* The elephant, the camel, the horse, the ass, the ox, the sheep, the goat, the hog, the dog, the cat, the lama, the vigogne, the buffalo; the hen, the swan, the guiney hen, the duck, the peacock, the pheasant, and pigeon.

remote from any continent, and have, till very lately, remained for ever unknown. It appears that these species have followed man in all his emigrations. In south America, where none of our animals could possibly arrive, we find the pecari and wild hen, which, though smaller and a little different from the hog and hen of our continent, must be regarded as a species so much allied that they might easily be reduced to a domestic state. But savage man, having no idea of society, is not solicitous about that of animals. In the regions of south America, the savages have no domestic animals. They destroy indifferently the good with the bad species. They select none for the purposes of rearing and multiplying them; while a single fertile species, like that of the *bocco* *, which is at their command, would furnish them, with very little attention, more subsistence than they can procure by their laborious and painful huntings.

Thus the first mark of man's civilization is the empire he assumes over the animals; and this first mark of his intelligence becomes afterwards the greatest evidence of his power over Nature: For it is only after he subjugates and tames animals, that he is enabled, by their assistance, to change the face of the earth, to convert deserts into fertile ground, and heath into corn. By multiplying useful animals, he augments the

* A large and very prolific bird, whose flesh is as good as that of the pheasant.

the quantity of life and motion on the surface of the earth ; he, at the same time, improves the whole race of beings, and ennobles himself, by transforming the vegetable into the animal, and both into his own substance, which afterwards diffuses itself by a numerous multiplication. He every where produces plenty of provisions, which is always succeeded by great population. Millions of men exist in the same space which was formerly occupied by two or three hundred savages, and millions of animals where only a few individuals existed. By him, and for his use, all the precious germs are unfolded ; the productions of the noblest kinds are alone cultivated ; upon the immense tree of fecundity the fruitful branches are alone brought to perfection.

Grain, of which man makes bread, is not the gift of Nature, but the fruit of his researches and of his knowledge in the first of all arts. In no quarter of the earth has wild corn been ever found : It is evidently an herb brought to perfection by his care and industry. This precious plant he must have selected out of many thousands. He must have sown and reaped a number of times, in order to discover its fertility, which is always proportioned to the manure and culture bestowed upon the soil : And the singular quality possessed by wheat of resisting, in its early state, the cold of our winters, though, like all other annual plants, it perishes

after yielding its seed, and its no less wonderful qualities of being nutritious and agreeable to all men, to many animals, accommodated to almost every climate, and can be long preserved without corruption, and without losing its power of reproduction ; all these circumstances concur in proving that it is the most happy invention ever discovered by man ; and, however ancient it may be supposed, it must have been preceded by the art of agriculture founded upon science, and brought to perfection by experience and observation.

If more modern and even recent examples of man's power over the nature of vegetables are required, we have only to compare our pot-herbs, our flowers, and our fruits with those of the same species as they existed fifty years ago. This comparison may be instantly made, by inspecting the great collection of flowers, which was begun in the time of Gaston d'Orleans, and continued to this day, in the Royal Garden. We shall then perceive, perhaps with surprise, that the most beautiful flowers of that period, as the ranunculi, pinks, tulips, auricula, &c. would now be rejected, not by florists alone, but by the most vulgar gardeners. These flowers, though then cultivated, were not far removed from their natural state. A single row of petals or flower leaves, long stamina, and hard or disagreeable colours, without variety, and without delicate shades, are the rustic characters

ters of savage nature. Our pot-herbs consisted of a single species of succory, and two of lattuce, both very bad; but we have now more than fifty kinds of lattuce and succory, all of which are good. Our best fruits and nuts, which are so different from those formerly cultivated, that they have no resemblance but in the name, must likewise be referred to a very modern date. In general, substances remain, and names change with times. But, in this case, names remain, and substances are changed. Our peaches, our apricots, our pears, are new productions with ancient names. To remove every doubt upon this subject, we have only to compare our flowers and fruits with the descriptions, or rather notices of them, transmitted to us by the Greeks and Romans. All their flowers were single, and all their fruit trees were wild stocks, and their species very ill chosen: Their fruits, of course, were small, dry, sour, and had neither the flavour nor the beauty of ours.

These new and good species originally sprung from the wild kinds; but, how many thousand times have their seeds been sown before this happy effect was produced? It was only by sowing and rearing an infinite number of vegetables of the same species, that some individuals were recognised to bear better and more succulent fruit than others; and this first discovery, which supposes much care and observation, would have
 , remained

remained for ever useless, if a second had not been made, which implies an equal degree of genius as the first required of patience; I mean the mode of multiplying by engrafting those precious individuals, which unfortunately cannot propagate, or transmit their excellent qualities to their posterity. This fact alone shows that these qualities are purely individual, and not specific; for the seeds of these excellent fruits, like the inferior kinds, produce nothing but wild stocks, which are essentially different.

By means of engrafting, however, man has in a manner created secondary species, which he can multiply at pleasure. The bud or small branch, when united to the wild stock, retains that individual quality which it could not transmit by its seed; and, in order to produce the same fruit as its original parent, it requires only to be developed. The fruits receive none of the bad qualities of the wild stock; because it has not contributed to their formation: It is not their mother, but their nurse, which only assists their growth by conveying nourishment to them.

In the animal kingdom, most of those qualities which appear to be individual, are propagated and transmitted in the same manner as their specific qualities. It was, therefore, more easy for man to have influence upon the nature of animals than upon that of vegetables. Particular
races

races in any species of animals are only constant varieties which are perpetuated by generation. But, in the vegetable kingdom, there are no races, no varieties so constant, as to be perpetuated by reproduction. In the species of the hen and pigeon, a great number of races have been very lately produced, all of which propagate their kinds. In other species, we daily rear and improve races by crossing the breeds. From time to time, we naturalize and tame foreign or wild species. All these recent examples show, that it was long before man knew the greatness of his power, and that he is not yet fully acquainted with its extent: It depends entirely on the exercise of his intellect. Thus the more he shall observe and cultivate nature, the more expedients he will discover for making her submit, and for drawing from her bosom fresh sources of riches, without diminishing the inexhaustible treasures of her fertility.

What influence might not man acquire over his own species, if his inclinations were always directed by his intelligence? Who knows to what degree he might improve his moral as well as his physical nature? Is there a single nation who can boast of having arrived at the best of possible governments, a government which would render all men not equally happy, but less unequally miserable, by attending to their preservation, by softening their labours, and sparing their

their blood by cultivating peace and procuring abundance of provisions: This is the moral end of every society of men who are anxious to improve their condition: And, with regard to the physical part of our nature, have the medical and other arts, whose objects are health and preservation, made an equal progress as the arts of destruction invented for the purposes of war and carnage? In all ages, it appears that man has reflected deeper and made more researches concerning evil than good. In every society there is a mixture of both; and as, of all sentiments which affect the multitude, fear is the most powerful, great talents in the art of doing mischief were the first which struck the mind of man; he was afterwards occupied with the arts of amusement; and it was not till after long experience in these two means of false honour and unprofitable pleasure, that he at last recognised his true glory to be science, and his true happiness peace.

T H E E N D.



I N D E X.

A

Ætna, Mount, a description of it, 147. 166. Dimensions of its crater, 150. Every eruption of it produces a new mountain, 151. Dangerous to descend its crater, 155. Sometimes falls in, 156. Ætna one of the primitive mountains, *ib.* Did not burn in the days of Homer, 157. The circumference of its base, 165. Not a single, but an assemblage of volcano's, 166. Its summit at present throws out nothing but smoke, 166. Pindar first takes notice of its eruptions, 168.

Agde, Cape, an extinguished volcano, 200.

Air, of its state on the top of high mountains, 117. Not more compressed in the plains than in the mountains, 118. Nearly of equal density at all heights, 120.

Albano, see Lakes.

Aleutes, islands of, described, 373. 375.

Alps, fossil shells found in them, 42. 43. Description of their glaciers, 358.

America, a recent land, 13. Of its discovery, 17. Fossil shells found in it, 38. 39. And the tusks of elephants, 274. Of a north-east passage to it, 367. Of the north-west passage, 372. Tschutschis pass from Asia to America, 374. Account of the islands between America and the north of Asia, 375. Peopled probably from Asia, 380.

Ammonis, See Cornua.

Anadir. See Andrien.

Andrien islands described, 373.

Animals, useful ones, tamed by man, 403. Man's power over them, 404.

Arts first invented in the north of Asia, 384.

Arthenay, M. de, his account of Vesuvius, 172.

Ascension island formed by a volcano, 194.

Asia, doubtful whether the Russians ever doubled the northern point of it, 367. Of a north-east passage between it and America,

- merica, *ib.* Captain Bering's account of the islands between the two continents, 375. Science first arose in the north of Asia, 384.
 Astronomy first known and cultivated in the north of Asia, at a very remote period of antiquity, 385. Very imperfectly known till lately, 389.
 Atlantic, of its northern parts, 86.
 Atmosphere, of its height, 121.

B

- Barbarous nations, their ravages, 394.
 Barometer, how the height of mountains is measured by it, 117.
 Basalts found in the isle of Bourbon, 195. And in many other places, *ib.* 199. The manner in which they are formed, 212.
 Beds. See *Strata*.
 Bering, Captain, his account of the islands between the north of Asia and America, 375.
 Bomare, M. de, observed vestiges of volcano's in the territory of Cologne, 203.
 Bones found between two strata of rock, 249. And in a solid rock, 250. Those of the elephant and hippopotamus found in Siberia and north America, 277. Of some enormous animal found near the banks of the Ohio, 289. Large bones of the supposed King Teutobochus described, 338, &c.
 Bosphorus, the Mediterranean sea elevated by its rupture, 157.
 Bouguer, his experiments concerning the depth to which the sun's rays can penetrate water, 266. Remarks on them, 267.
 Bourbon, isle of, extinguished volcano's in it, 193. 194. Basalts found in it, 195.
 Brahmins calculate eclipses, 387.
 Brydone, Captain, his description of Scylla and Charybdis, 111. His facts and remarks praised by the Count de Buffon, 158. His remarks on the eruption of *Ætna* in 1755, 170.

C

- Caille, l'Abbé de la, his account of extinguished volcano's in the isle of France, 193. And of the isle of Bourbon, *ib.*
 Calcarious

- Calcareous substances capable of being vitrified, 32. Composed entirely of the reliicks of aquatic animals, 273. 274.
- Canada, fossil shells found in it, 39.
- Caspian sea only a lake, 100. Formerly much larger, 352.
- Catania, often destroyed by the eruptions of *Ætna*, 159. 164.
- Cataracts, remarks concerning them, 76. That of Terni falls 300 feet, 77. That of Niagara only 156, *ib*.
- Caverns, the effects of their sinking, 60. Of those formed by the primitive fire, 222.
- Ceylon, island of, formerly united to the continent, 354.
- Charlotte islands, smoke issues from one of them, 195.
- Charybdis, its current described, 111.
- Chinese calculate eclipses in a rude manner, 388. Never invent nor bring any thing to perfection, 388. 389.
- Climate, may be warmed by human art and industry, 396.
- Coal, of its composition, 343.
- Cold, its phaenomena in Greenland, 88.
- Collinson, Mr, his account of enormous bones found near the banks of the Ohio, 288.
- Columbus vindicated from an aspersiion, 18.
- Columns, basaltic, how they are formed, 212.
- Compass, Mariners, of its invention, 16. Known in the days of Homer, 17.
- Condamine's description of Vesuvius, 174. 179. His account of the nature of lava, 217.
- Continents, of their extent, 8. Calculation of our Continent into leagues square, 9. Calculation of the Continent of America into leagues square, 10. Of the form of Continents, 12. Analogies between the figure of the New and Old Continents, *ib*. Formerly covered with the ocean, 45. Period when the two Continents were separated, 286.
- Cook, Captain, his discoveries in the southern hemisphere, 15.
- Cordelieres, fossil shells found in them, 319.
- Corn never found in a natural state, 405.
- Cornua Ammonis, their great variety, 46. 48. 49. An immense one found in Champagne, 304.
- Croghan, Mr, his account of enormous bones found near the banks of the Ohio, 289.
- Currents, run perpetually from Guiana to the Antilles, 18. The probable cause of this phaenomenon, 19. , Double currents

rents in some parts of the ocean, 79. 80. &c. Description of the current of Mosche or Male on the coast of Norway, 107. Of that of Scylla and Charybdis, 111.

D

Deslandes, his experiments which prove the existence of double currents in some parts of the ocean, 80. &c.

Dunkirk, the sea has been gradually retiring from its coast, 255.

E

Earth, of its distance from the sun, p. 1. Of its interior rock, 30. Of the inequalities on its surface, 50. Effects produced by the sinking of its caverns, 60. Causes of its fissures, 62. Elevated at the equator and depressed at the Poles, 259. 261. Possesses an internal heat, 260. 261. The materials of which it is composed generally of a vitreous nature, *ib.* 270. Was formerly in a state of fluidity, 261. 285. Gensanne's experiments on its internal heat, 263. Mairan's experiments on the same subject, *ib.* Its whole surface has been covered with the ocean to the height of 1500 or 2000 fathoms, 319. Its declivity more rapid on the west than on the east coasts, 349. Earthquakes, the causes of them, 138. Generally precede eruptions of volcano's, 141. A mountain in Iceland sunk by one, 143. Other dreadful effects of them, 144. Generally precede eruptions of volcano's, 158.

Eclipses calculated by the Brahmins, 387.

Elephants, their tusks and skeletons found in Siberia, 274. And in North America, 275. Formerly inhabited the northern regions, 276.

Empedocles, the ruins of his tower still exists on Mount Ætna, 155.

Engrafting, the usefulness of its invention, 408.

Epochs of Nature, 276.

Eruptions of volcano's described, 158. Cease after the flowing of the lava, 159. New mountains formed by them, 162. A great one in 1669 from Ætna, 163. Those of Ætna first mentioned

mentioned by Pindar, 168. A dreadful one in 1755, 169.
Eruptions of Mount Hecla, 187.

F

Fire, its effects in hardening bodies, 63, 64. Of the caverns formed by the primitive fire, 222. Subterraneous fire one of the chief causes of the revolutions which the globe has undergone, 228.
Fishes, can live in water so hot as from 50 to 60 degrees of the thermometer, 321. 322. Of petrified fishes found in slate, 341.
Fissures of the earth, their causes, 62. Metals found in them, 307.

Fossil shells. See *Shells*.

Fossil wood, found in many places, 343.

Fougeroux, M. de Banderoy, his description of Solfatara, 203. Of those in other parts of Italy, 206. His account of the nature of lava, 218. His description of petrified wood, 244.

Fountains, description of hot ones, 206. &c.

Foxes, islands of, described, 375.

France, height of its mountains, 53. 54. Extinguished volcano's in it, 196.

France, isle of, full of extinguished volcano's, 193. Basalts found in it, 195.

G

Genfanne, M. de, his experiments on the internal heat of the earth, 263.

Giants, of different animals, formerly existed, 324. Examples of them, 325. Individual human giants produced in every climate, 331. Races of them in Asia, 331. 332. Dispute concerning the large bones of the supposed King Teutobochus, 333. Other examples of a similar kind, 337.

Gibraltar, Straits of, the Mediterranean sea elevated by its rupture, 157.

Glaciers, a description of them, 358. Are constantly augmenting, 363.

Globe,

Globe. See *Earth*.

Gold, and sometimes silver and copper, found in a pure state, 309.

Grain, of which bread is made, an artificial production, 405.

Greenland, of its situation with regard to temperature, 88.

Guatemala destroyed by an eruption of Pacayita, 172.

Guettard, his account of extinguished volcano's in France, 196.

His description of turf, 234. His account of bones found in a rock, 250.

Guiana, its rivers near each other, and deposite vast quantities of mud in the sea, 355. Its temperature heated by cultivation, 398.

H

Heat, of the sun, how far it can penetrate water, 262.

Heberden's description of the Peak of Teneriff, 190.

Hecla, Mount, a description of it, 185. Its eruptions, 188.

Habicot, his dispute with Riolan concerning the large bones of the supposed King Teutobochus, 333.

Hills. See *Mountains*.

Hippopotamus, bones of it found in Siberia, 274. And in North America, 275. Formerly inhabited the northern regions, 276.

Homer, Mount Ætna did not burn in his days, 157.

Hudson's bay, its discovery revived the project of a north-west passage, 94.

I

Japanese islands abound with volcano's, and more subject to earthquakes than any other country, 354.

Ice found in much lower latitudes in the southern than in the northern hemisphere, 14. Floating mountains of it, their origin, 89. 90.

Indian ocean has undergone great revolutions, 353.

Josephus, the Jewish historian, first mentioned the period of six hundred years, without understanding its value, 389.

Iron

- Isle of France, full of extinguished volcano's, 193.
 Iron, some mountains entirely composed of it, 313.
 Ivory, great quantities of it found in Siberia and North America, 276. 277. Its structure, 281.

K

- Kadjack, island of, described, 376.

L

- Lakes, the Caspian sea only a lake, 108. Of the salt lakes in Asia, 102. Lake Albano the mouth of an ancient volcano, 181.
 Land, of its sinking and derangement in certain places, 228. Of the changes of sea into land, 255.
 Lava, not the first effect of volcano's, 158. Eruptions cease after the lava flows, 159. The destruction produced by it, *ib.* Catania often destroyed by it, *ib.* The vast extent of some of its torrents, 160. Long before it acquires a vegetable soil, 161. Its great thickness, *ib.* Antiquity of the world computed from successive strata of lava and vegetable soil, 163. Lavas of Vesuvius described, 176. Of the motion of lavas, 209. Require a long time to cool, 215. Of the nature of lavas, 217. See *Eruptions and Volcano's.*
 Lavanges, or great masses of snow and ice rolling down from high mountains, described, 125. Precautions used by the natives against their dreadful effects, 127.
 Light, how deep it can penetrate water, 265. That of the moon has no sensible heat, 268.
 Load-stone, mountains composed of it, 314.
 Lunifolar period first discovered in the north of Asia, 385.

M

- Madagascar, basalts found in it, 195. Formerly united to the continent, 354.
 Maillés, a savage people, described, 351.
 Vol. IX. D d Mairan,

- Mairan, his experiments on the internal heat of the earth, 263.
 Man, account of his original state, 381. The first monuments of his art, *ib.* His progress in the arts, 382. The first men of science were produced in the north of Asia, 384. His powers, 392. 396. 404. Tames animals for his use, 403.
 Mariner's compass, of its invention, 16. Known in the days of Homer, 17.
 Mazeas, M. l'Abbé, his account of a quarry of petrified wood, 242.
 Mediterranean sea elevated by the rupture of the straits of Gibraltar and of the Bosphorus, 157.
 Metals, of the situations in which they are found, 307. Some of them exist in a pure state, 309.
 Mines, the degrees of heat discovered in them, 264.
 Moon, its light has no sensible heat, 268.
 Morse, its bones found in northern regions, 279.
 Mosche or Male, a famous current on the coast of Norway, described, 107.
 Mountains, primitive ones composed of vitrescent materials, 31. Fossil shells found in very high mountains, 44. Of their height, 50. Height of the most elevated in the province of Quito in Peru, *ib.* Those of South America the highest, 51. The height of Norwegian mountains, and of those of France, 53. 54. Of the direction of mountains, 55.—60. Of their formation, 60. Of the inclination of their strata, 67. Of their Peaks, 70. How to measure their height by the barometer, 117. Mount Etna described, 147. Mount Hecla described, 185. Some mountains composed entirely of iron, 313. Others of load-stone, 314.
 N
 Naples, its streets paved with lava, 176. Mountains in its environs are masses of burned matter, 181.
 Nature, monuments of her great antiquity, 274. 275. Her epochs, 276. 305. Man's power over her, 392. 396. 404.
 Niagara, cataract of, falls 156 feet, 76.
 North-west passage, Captain Phipps's remarks on it, 90. 91. Raynal's observations on this subject, 94.

Norway,

Norway, height of its mountains, 53. Their direction, 58.
Description of the current of Mosche or Male on its coast, 107.
Nux, M. de la, his account of water-spouts, 129.

O

Ocean. See *Sea*.

Ohio, enormous bones found near its banks, 289.

Olympus, its height, 53.

Otaheite, stones in it bear evident marks of fire, 194.

P

Pacayita, a water volcano, destroyed the city of Guatimala, 172.

Pallas, M. found bones of the elephant, and a skeleton of the rhinoceros, in Siberia, 288. Supposes the Caspian sea to have been formerly much larger than it is at present, 352.

Paris, fossil shells found in its neighbourhood, 41.

Passage, of the practicability of a north-east one between the Old and New Continents, 367. Of the north-west passage, 372.

Peak of Teneriff, its height, 53. Dr Heberden's description of it, 190.

Peaks of mountains, how formed, 224.

Peru, petrified shells found there, 39.

Perronet, his account of the sinking of certain lands, 228.

Petrified shells. See *Shells*.

Petrified wood, an account of it, 237. How its age may be ascertained, 239.

Phipps, Captain, account of his voyage to the north seas, 90. 91.

Pindar, first mentions the eruptions of *Ætna*, 168.

Planets, additions concerning their formation, p. 1. Of the matter of which they are composed, 3. Of the relation between their density and celerity, 4. Of the relation between their density and the degrees of heat to which they are exposed, 6.

Plants, can vegetate in water so hot as from 50 to 60 degrees of the thermemeter, 321. 325.

Pyrenees, fossil shells found in them, 42. 223.

Q

Quito, height of its mountains, 50.

R

Recupero, Signior, his account of an ancient lava, 160. Computes the antiquity of the world from successive strata of lava and vegetable soil, 163.

Rhinoceros, its bones found in Siberia, 274. And in North America, 275.

Rhone, basaltic columns found on its banks, 199.

Riolan, his dispute with Habicot concerning the large bones of the supposed King Teutobochus, 333.

Russia, great quantities of ivory found in it, 277.

S

Salt Lakes, of those in Asia, 102.

Sea, of productions of it found in the bowels of the earth, 34. 35. Their form and number prove that they were formerly animals which existed in the ocean, 36. Formerly covered what is now dry land, 37. to the height of two thousand fathoms, 61. Of its saltiness, 75. Limits of the South Sea, 78. Double currents in it, 79. 80. &c. Caspian sea only a lake, 100. Nature of the soil at the bottom of the sea, 104. Sicilian sea has sunk considerably, 156. Of the retiring of the sea from various coasts. Equally warm as the interior parts of the earth at the same depths, 264. Its fluidity not owing solely to the sun's rays, 265. How far the light can penetrate through its water, 266. Has covered the whole surface of the earth to the height of 1500 or 2000 fathoms, 319. Caspian sea formerly much larger, 352.

Sciences first invented in the north of Asia, 384. Neither originated in China nor in India, 388.

Scylla, its current described, 111.

Shells found in the bowels of the earth near Toulon, 24. Some fossil

- fossil shells perfectly similar to those which now exist in the sea, 35. 36. Places where they are found, 38. 39. &c. Of ten different from those in the neighbouring seas, 40. 274. Petrified more numerous than fossil shells, 45. 46. Beds of them found in the Pyrennees, 223. Likewise found in the Cordelieres, 319. And in the Alps, 42. 43. 364.
- Siberia, Fossil shells found in it, 40. And the tusks of elephants, 274.
- Sicilian sea has sunk considerably within these 2500 years, 156.
- Sicily, Virgil wonderfully exact in his geography of it, 165.
- Slate, of petrified fishes found in it, 341.
- Soil, vegetable, account of it, 68. Nature of that at the bottom of the sea, 104.
- Solfataras, neither active nor extinguished volcano's, 203. That near Naples described, 203.
- Spitzbergen. See *Greenland*.
- Strata of the earth, a description of them in different parts of the globe, 22. 24. 26.—29. 36. Of their inclination in mountains, 67.
- Steller, his remarks on the volcano's of Asia, 173.
- Sulphur sublimed in Solfatara, 204.
- Sun, of his distance from the earth, p. 1. Of the matter of which he is composed, 3. How far his rays can penetrate water, 262.
- Sweden, height of its mountains, 153.
- Switzerland, the height of its mountains, 54. Description of its glaciers, 359.

T

- Taprobana, a country swallowed up by the sea, 353.
- Teeth, of the hippopotamus and elephant, found in Siberia, 274. And in North America, 275. Enormous ones found near the banks of the Ohio, 288.
- Teneriff. See *Peak*.
- Terra Australis, of the many fruitless attempts to discover it, 14. Captain Cook's voyage and discoveries in the South seas, 15.
- Torré, P. de la, his description of Vesuvius, 182.

Toulon,

- Toulon, a description of the strata in its neighbourhood, 22.
 Tschutschis, a people who pass from Asia to America, 374.
 Turf, concerning its nature and composition, 233. M. Guettard's account of it, 234.
 Tusks of elephants found in Siberia, 274. And in North America, 275.

V

- Ulloa, Don, found petrified shells in the mountains of Peru, 39.
 Vapours, the heights at which they freeze in different places, 52.
 Vegetables, man's power of changing their nature, 405.
 Virgil, wonderfully exact in his description of Sicily, 165.
 Vesuvius, Mount, a description of it, 152. A feeble volcano when compared with *Ætna*, 153. A wind penetrates the mountain, 172. Its ancient compared with its modern state, 172. Condamine's account of it, 174. 179. Its height, 175. Its state in the year 1753, *ib.* P. de la Torr 's description of it, 182.
 Volcano's in South America, 51. 52. Of the changes they undergo, 147. That of *Ætna* described, *ib.* That of Vesuvius described, 152. Of their eruptions, 158. Often throw out torrents of water, 168. 172. Steller's remarks on those of Asia, 173. Volcano's communate with the sea, 173. 174. Of extinguished volcano's, 192. 196.
 Voltaire, an apology for the author's treatment of him, 34.

W

- Water-spouts, a description of them, 189.
 Waters. See *Sea*. Theory of running waters, 72. Description of hot fountains, 206.
 Winds, of reflected ones, 116. Some winds have a regular variation, 123. Of their violence in some countries, 128.
 Wood, subterraneous, found in many places, 237. Examples of fossil wood, 343.

DIRECTIONS to the BINDER.

Place Plates CCCII. CCCIII. CCCIV. CCCV. CCCVI. CCCVII.
at the end of the volume.

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- Page. 47. line 6. *for Pelasgie, read Pelasgae.*
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49. *for plates I. II. III. read CCCII. CCCIII. CCCIV.*
106. line 16. *for archin read urchin*
186. line 13. *delete that.*
360. line 14. *for freeze read freezes.*

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11

Page 11

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11

Page 11

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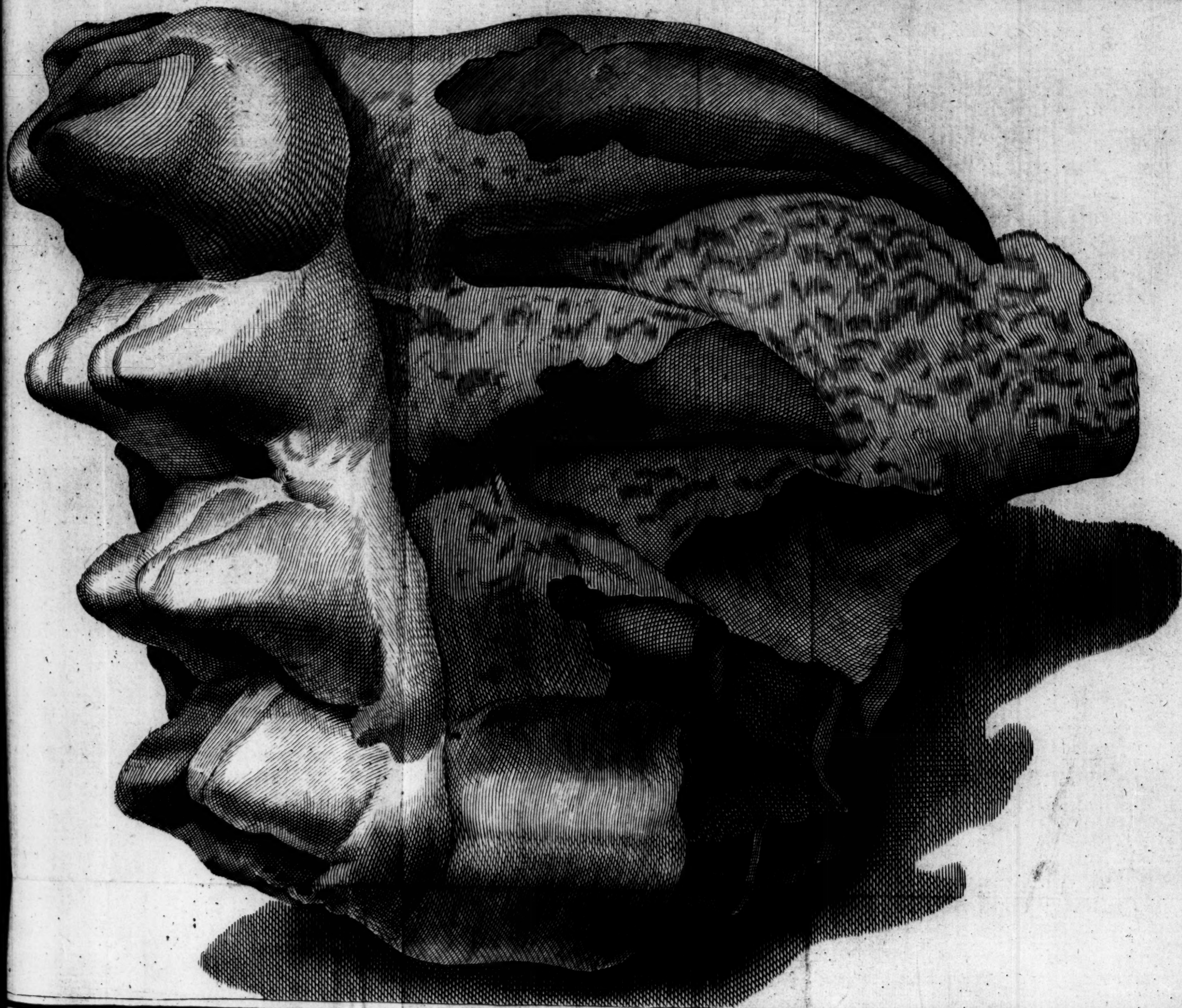
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Page 11

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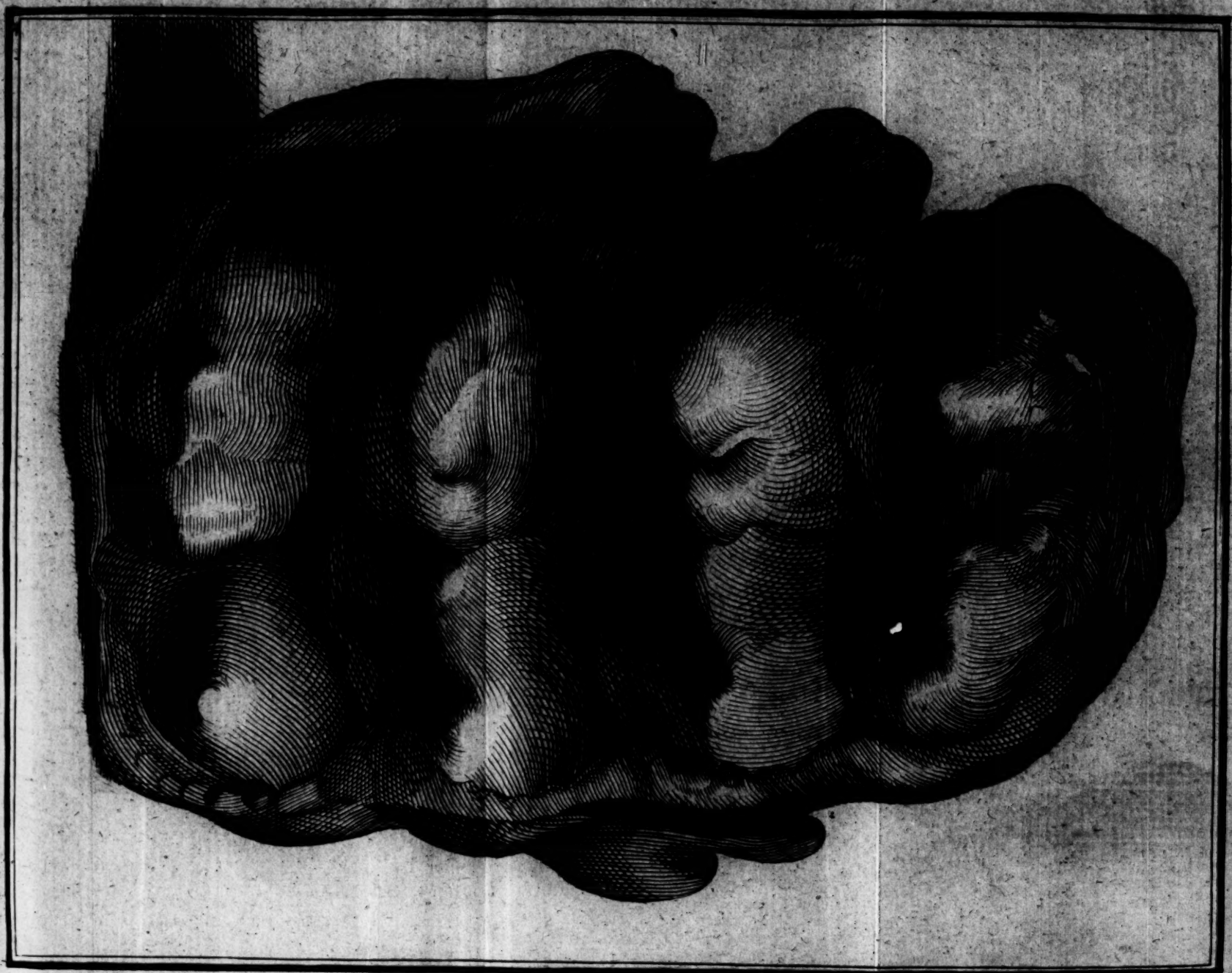
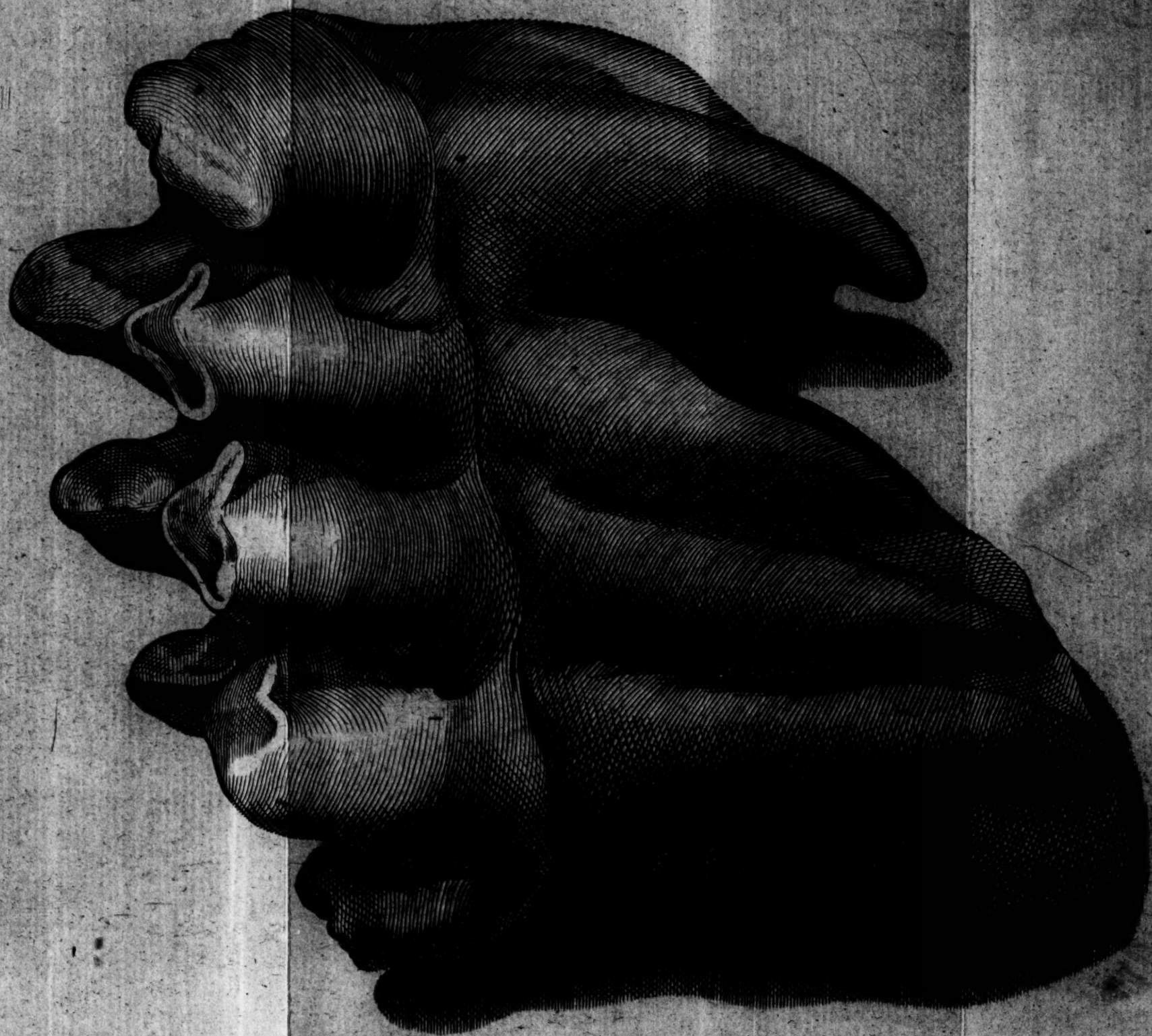
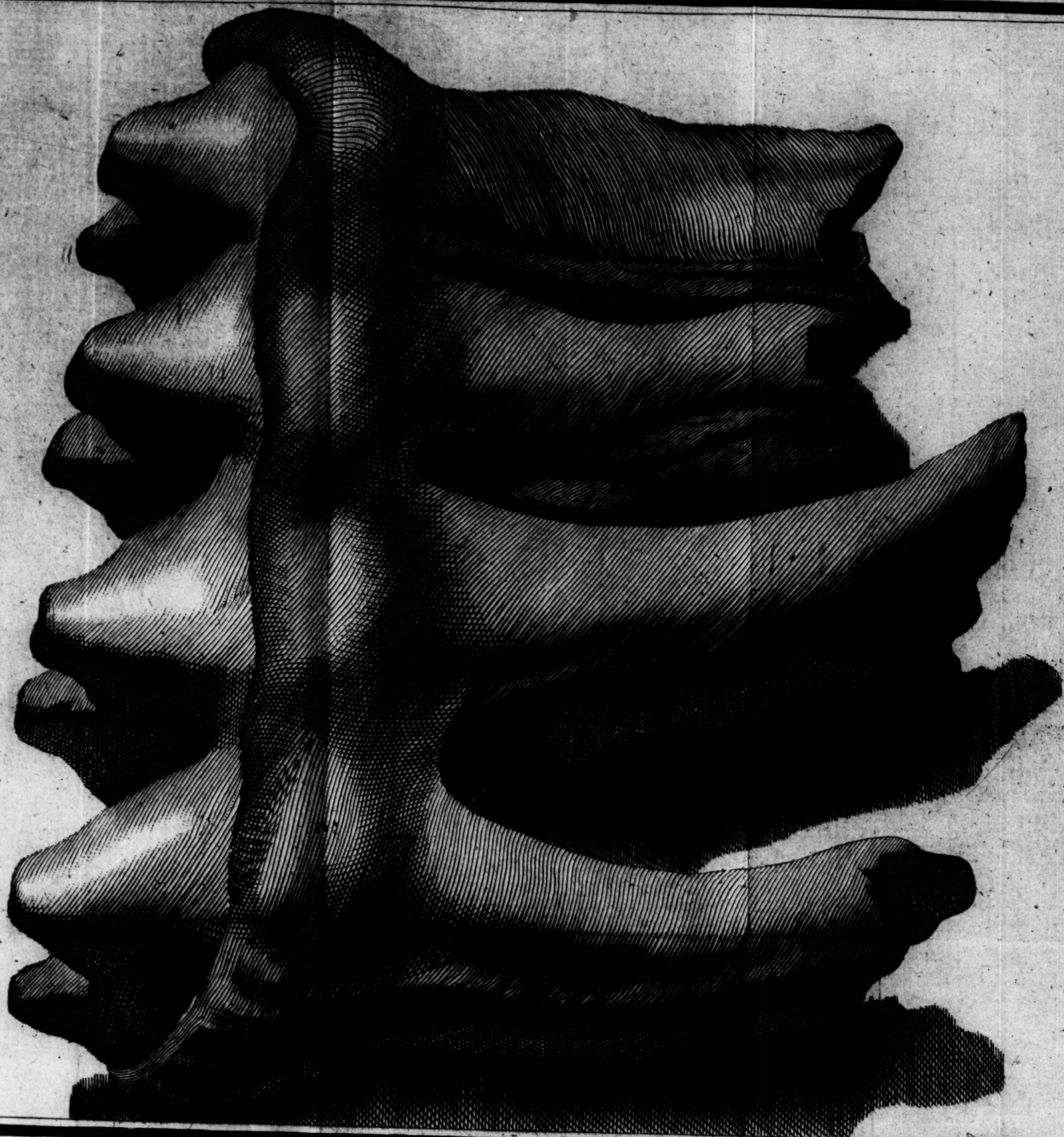


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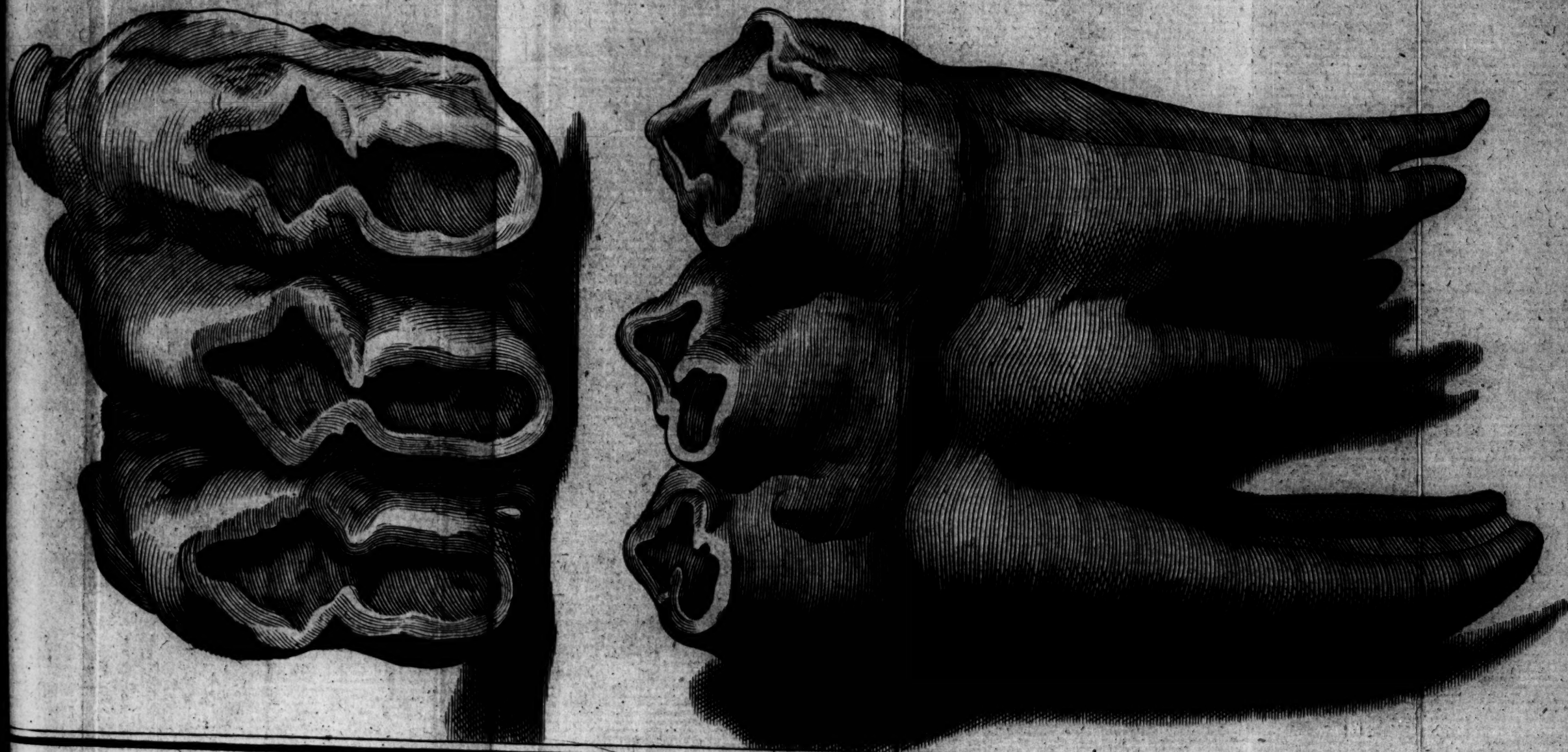




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